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WEEKLY July 4–10, 2020

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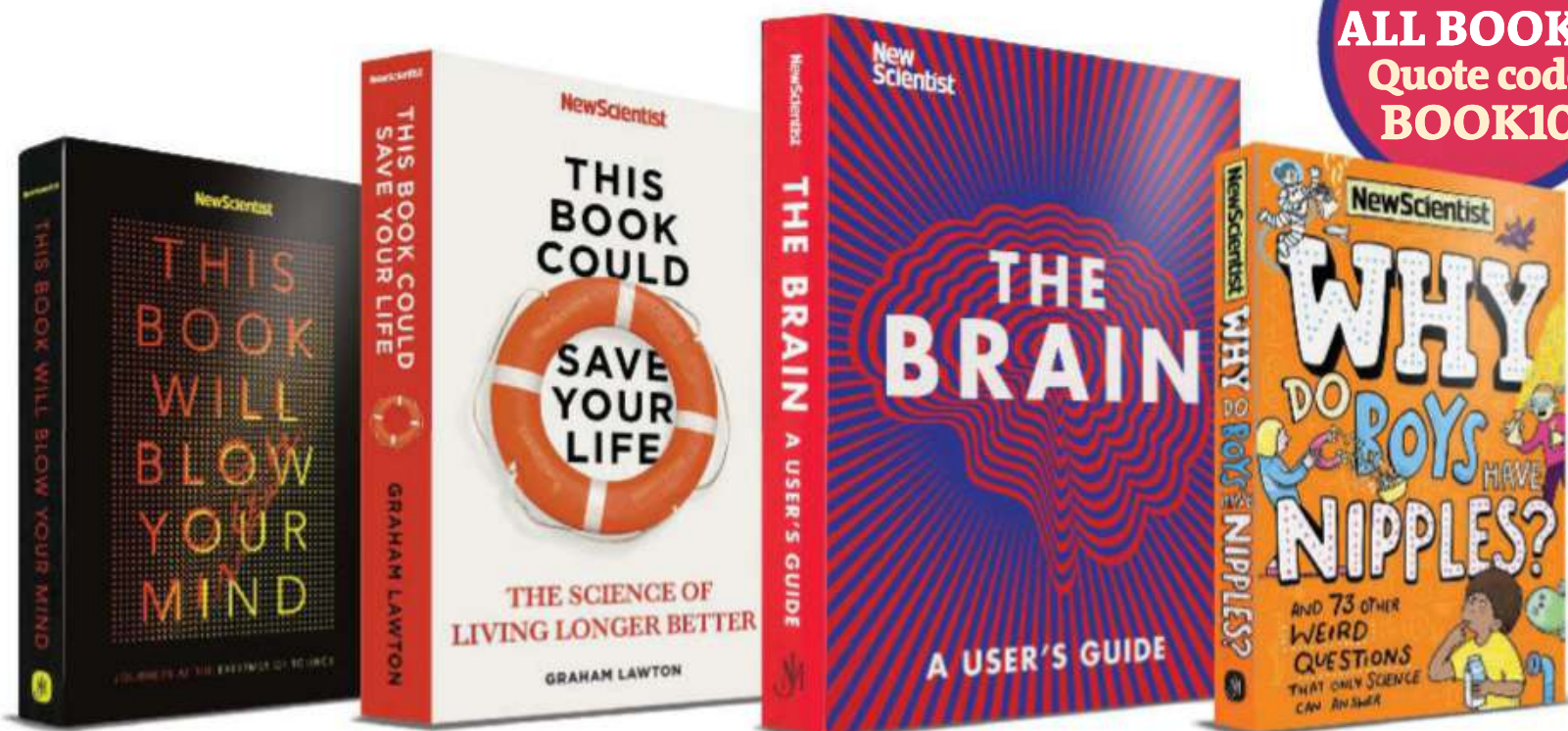
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On the cover

10 Coronavirus special: Immunity

The latest evidence, and why it offers new hope

36 Rebuilding green

How to put the environment first in a post-covid world



Vol 247 No 3289

Cover image: Vanessa Branchi

30 Dominance v prestige
The science of leadership

15 Quantum leap?
Tech firm claims new computing record

40 Hidden gravity
Audacious new plan to detect dark matter

14 Biggest lightning flash ever

14 How parenting changes you

17 Hints of exomoons

18 The ancient origin of sled dogs

36 Features
“There is no way to have net-zero emissions and aviation as it was before covid-19”

News

7 Worldwide surge

Rise in infections amid fears of a second wave of covid-19

9 Mass testing

Moves begin to check whole city weekly for coronavirus

15 Superbugs in the shower

The drug-resistant bacteria lurking in your plumbing

Views

21 Columnist

Annalee Newitz on unusual methods of online protest

22 Letters

On the trail of the perfect contact-tracing app

24 Culture

The search for life on Mars is far from over

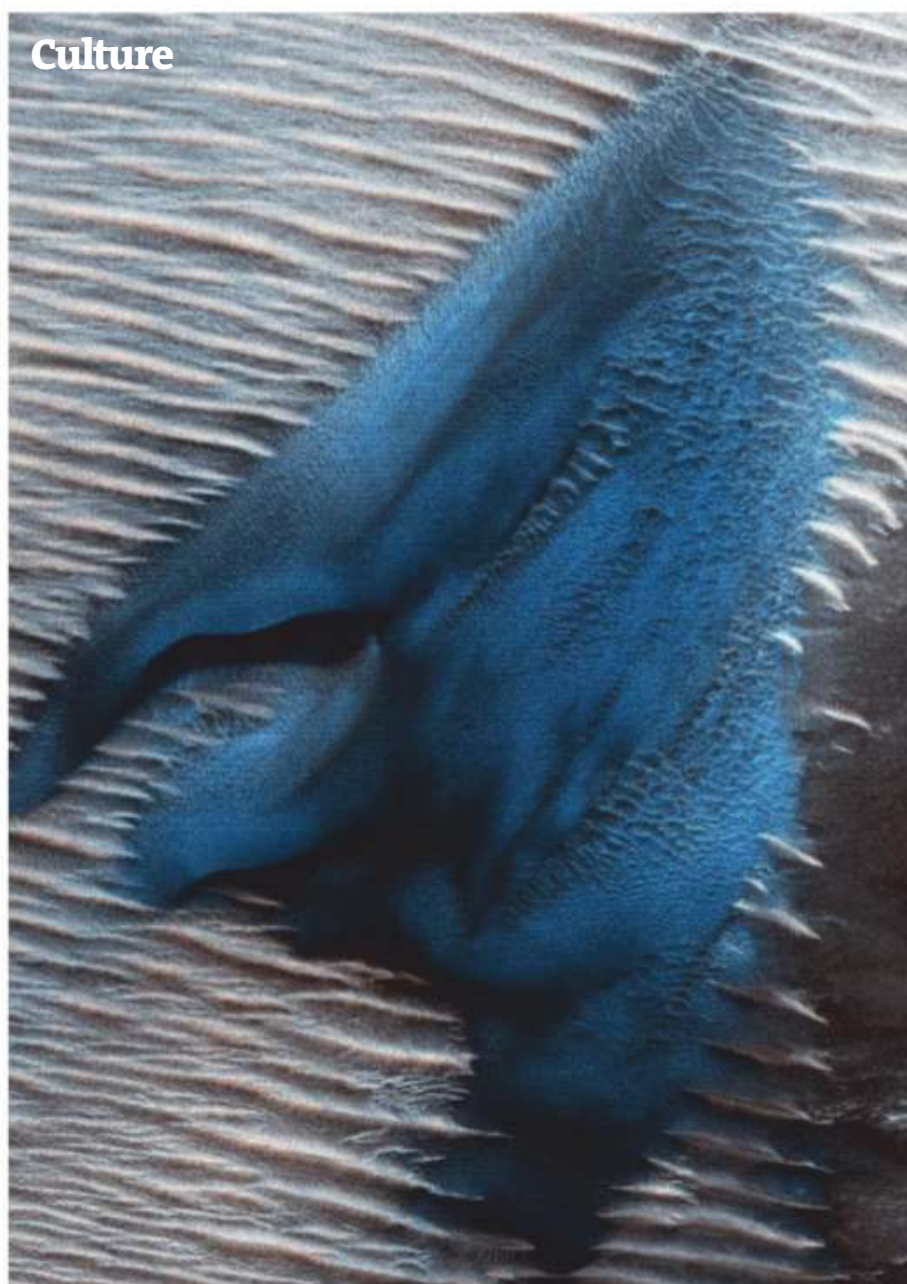
25 Culture

Shining a light on gender discrimination in science

28 Aperture

Foraging for plastic in Lake Victoria's polluted swamps

Culture



24 Sirens of Mars Inside the hunt for life on the Red Planet

Features

30 Dominance v prestige
Evolution tells us why there are two types of leader in today's world

36 Rebuilding green
How we can fix the climate as we reboot the economy

40 Hidden gravity
The detector with a billion sensors that may finally snare dark matter

The back pages

53 Puzzles
Quick crossword and the quiz

54 More puzzles
Can you work out what pattern the tiles should be in?

54 Cartoons
Life through the lens of Tom Gauld and Twisteddoodles

55 Feedback
Odorous offences in Bavaria and Vienna: the week in weird

56 The last word
Why some hairs stop growing at a certain length

Virtual events

What happened at the big bang?

Theoretical astrophysicist Dan Hooper reveals why recreating the conditions of the big bang is helping to uncover the biggest mysteries of the cosmos. Thursday 9 July at 6pm BST/1pm EDT and on demand.

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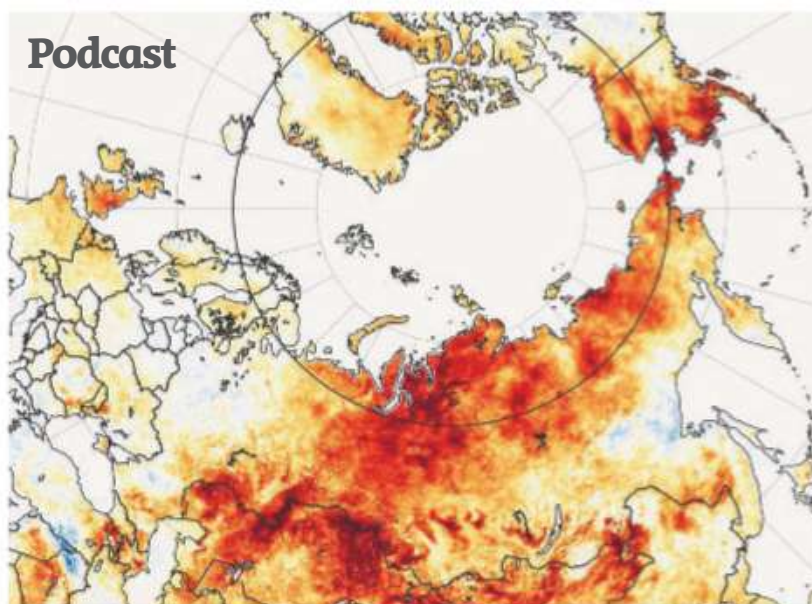
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The day's coronavirus coverage updated at 6pm BST with news, features and interviews.

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Heating up Temperatures in the Arctic hit 38°C

Video



Father figurer Anna Machin on the biological impacts of dadhood

Virtual events



The big bang Dan Hooper takes you back to the beginning of time



Reporting on the life and world-changing potential of scientific and technological advances is *New Scientist's* bread and butter. Sometimes, however, an innovation's scope is so great, and its societal effects so profound, that it is difficult to fully appreciate.

Artificial intelligence is a case in point. The advent of machines that feed on reams of our data to "learn" about us and the world is both immensely exciting and deeply troubling. AI tech, from medical bots to driverless cars, holds much promise to improve our lives; yet AI stands accused of sins such as exacerbating racial and other inequalities through algorithmic bias and undermining democracy by spreading fake news.

That is why I find the second issue of our new *Essential Guide* series so timely. Featuring the best recent *New Scientist* content on AI, carefully curated and brought bang up-to-date, it provides a much-needed opportunity to zoom out and form a balanced view of the technology.

On page 46 of this issue, you will find an excerpt, in the form of a classic article from AI researcher Toby Walsh, on that eternally fascinating question of whether machine intelligence will ever supplant us. If that piques your interest, you can get the full *Essential Guide* at all good newsagents, and online at shop.newscientist.com.

Emily Wilson

New Scientist editor



The New Scientist Weekly podcast

Episode 23 out Friday 3 July

Our weekly podcast has become the must-listen science show, bringing you the most important, surprising or just plain weird events and discoveries of the week. If you missed the earlier episodes you can still listen in to hear about:

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Consciousness from the body as well as the brain, record temperatures in the Arctic and long-term symptoms of covid-19

Episode 21

How to prevent future pandemics, how our brains might trigger a hibernation-like state, plus black lives matter and racism in science

Episode 20

Human cryptic mate choice, cracking nuclear fusion and countering coronavirus misinformation

Episode 19

How the UK got it wrong on coronavirus, mystery around chronic Lyme and Greta Thunberg's musical debut

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Hosted by *New Scientist's* Rowan Hooper and Penny Sarchet, new episodes are out each Friday. Follow us on Twitter **@newscientistpod**

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If memory serves

The way our bodies remember coronavirus infection may make a vaccine possible

THROUGHOUT the pandemic, SARS-CoV-2 has proved full of surprises, most of them nasty. Initially regarded as a respiratory virus, we now know it infects other organ systems, and can linger for months. It disproportionately kills people from poor and ethnic minority backgrounds and also men, for reasons that still aren't fully understood. It doesn't seem to be suppressed by warm weather or climates.

But the latest surprise is a nice one. Initial fears that the virus would fail to raise immune memory – the lengthy, sometimes lifelong, protection that we get from exposure to many viruses including measles – look exaggerated. It is still early days, but signs from patients point to a strong and long-lasting immune response (see page 10).

That is welcome news for two reasons.

It makes a vaccine more likely, and means that people who have recovered from the virus almost certainly can't get it again, at least in the short term. But it also brings complications.

One is that governments will be tempted to introduce “immunity

“Natural herd immunity is for the birds. The levels of infection required would kill millions and devastate health services”

passports” for people who have recovered, perhaps permitting them to travel or attend large gatherings, which those without passports would be banned from. That may seem like a good idea, but bioethicists warn that it could backfire, for example by creating perverse incentives to get infected and a black

market in stolen or forged passports. It could also be the start of a slippery slope to a more comprehensive system of health passports and surveillance.

The other fear is that it revives the canard that naturally acquired herd immunity will save us. That this was ever on the table beggars belief: without knowing whether natural immunity exists, positing herd immunity as an exit strategy is scientifically illiterate. Even now, natural herd immunity is for the birds. The levels of infection required would kill millions and devastate health services.

But herd immunity does remain the way out, if it is artificially created by vaccination. On that front, the latest science looks good. With infections rising globally (see page 7), we badly need it. ■

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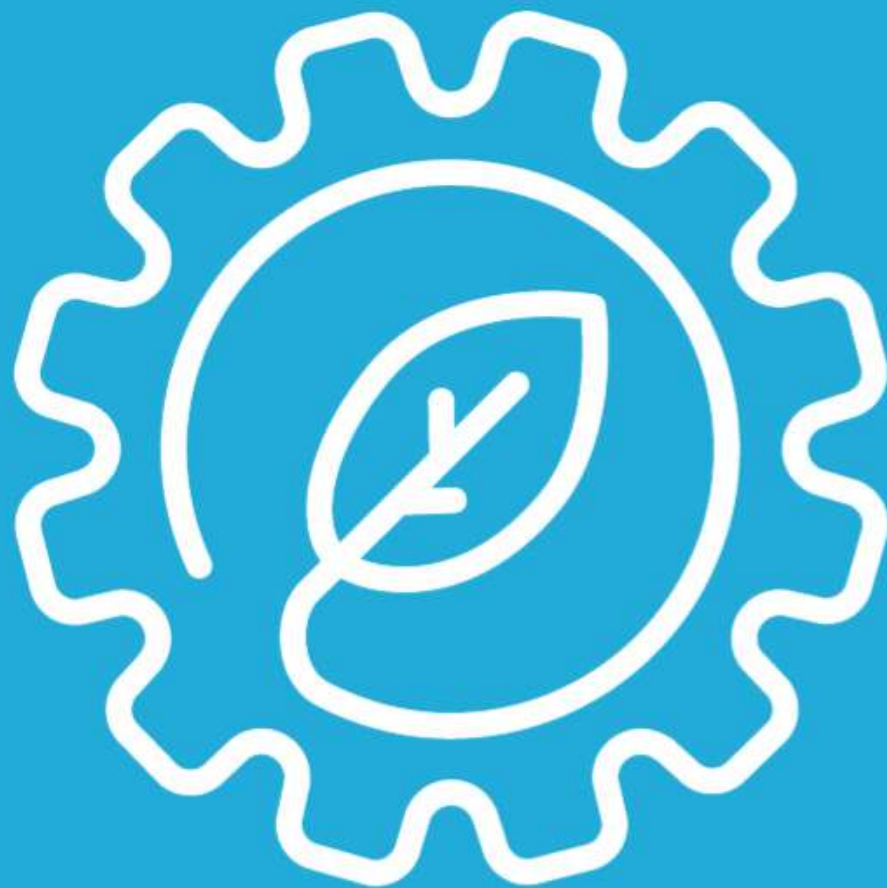
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**Adam
Vaughan**



REUTERS/SERGIO FLORES

People protest against mandatory mask-wearing in Texas

Ghani, whose colleagues have modelled epidemics at a state-level in the US, says many states began to relax restrictions while R was still above 1. She says: "I think it's inevitable we'll see increasing cases and deaths in the US."

In Europe, cases rose in the week commencing 15 June, the first increase in months. Sweden, Albania and Bosnia and

"Nearly 300 people who went to a Swiss nightclub were quarantined after one later tested positive"

Herzegovina were among the nations that the WHO identified as having a rise. Sweden said its increase was due to greater testing rather than fresh outbreaks.

Local outbreaks across Europe have seen authorities taking new action, such as nearly 300 people who went to a Swiss nightclub being quarantined after one person later tested positive. Meat-processing facilities, where people work close together, have emerged as the source of case clusters in several countries, including Germany.

However, the WHO has made it clear that not all local outbreaks are equal. The agency is less concerned about some clusters in Europe that were controlled with a "rapid and targeted response", including restrictions and ramped-up testing, than in places where there is no such quick and proportionate reaction.

David Heymann at the London School of Hygiene & Tropical Medicine says second waves are "not the right way to think about it" because, unlike flu, covid-19 seems to spread in summer. "It may be [better] to think about suppressing and unsuppressing. That's what the countries are going to have to do: unlock their suppressing activities and if they see suppression isn't working as they wanted it to do, they'll have to lockdown again," he says. ■

Cases flare up worldwide

Coronavirus infections are rising globally, including in some places that had brought the virus under control, reports **Adam Vaughan**

MORE than half a million people are now confirmed to have died from the coronavirus, as local outbreaks around the world trigger fears of a second wave of covid-19. Globally, a record 189,077 cases were reported on 27 June, and cases are rising in Africa, Asia and North and South America.

Some of the surge is due to greater testing, and the rate of deaths is yet to see an equivalent increase. However, the World Health Organization (WHO) believes the growth in daily cases is down to a genuine acceleration in the spread of the virus. "Intense transmission is going on in many communities in many parts of the world," a spokesperson says. There are also flare-ups in countries that successfully lowered infection rates but have since relaxed restrictions.

Azra Ghani at Imperial College London notes that in many countries that rapidly introduced lockdowns, such as South Korea, only around 5 per cent of people have had the virus. "Which means as soon as you start to open up and connections start to come back between countries, it's very likely to take off again," she says.

The South Korean government declared the start of a "second wave" of infections last week, due to small clusters of cases after an easing of restrictions in May. A jump in cases in the Australian state of Victoria has led to the reintroduction of lockdown in some areas of Melbourne. China has reimposed a lockdown on

400,000 people in Anxin county near Beijing after 18 new cases.

"We are likely to see, in every place, a relaxation and then maybe a ramping up of interventions again to control it. I expect we will see continual waves," says Ghani.

The US, which has the world's highest number of confirmed cases and deaths, has had an uptick in both in places that previously seemed to have the virus under control. Two months ago, almost all 50 states had an estimated reproduction number (R) of under 1, indicating that the epidemic was in decline. But according to one analysis, 33 now have an estimated R of 1 or above, meaning the virus will spread exponentially.



Daily coronavirus news round-up
Online every weekday at 6pm BST
[newscientist.com/coronavirus-latest](https://www.newscientist.com/coronavirus-latest)

Scotland could eliminate the coronavirus – if it weren't for England

As Scotland gets closer to suppressing the virus, cases from over the border will become a big problem, reports **Michael Marshall**

SCOTLAND is only weeks away from suppressing the coronavirus altogether, a situation that highlights the different approaches taken by the nation and England in recent months. While Scotland initially made many of the same mistakes as England, since late March, its government has acted on its own scientific advice.

The two nations responded to the coronavirus similarly from January and up until March, says Devi Sridhar at the University of Edinburgh. "There are a couple of things where Scotland's gone slightly earlier, but not radically."

One early Scottish success came in community testing for the disease. When Kate Mark at the National Health Service Lothian in Edinburgh realised that suspected cases were increasing, her team began testing people in their homes and set up one of the world's first drive-through testing centres. But on 12 March, the UK government abandoned all community testing efforts to focus on testing in hospitals and other healthcare settings, due to a lack of resources. From then on, the disease spread fast until, on 23 March, prime minister Boris Johnson announced a lockdown across the UK.

This wasn't soon enough to prevent waves of deaths in care homes in Scotland and England. In both nations, protecting social care had been deprioritised in favour of healthcare. When Scotland began collecting data on covid-19 in care homes on 11 April, 37 per cent of homes were already infected, according to a report co-authored by David Henderson at Edinburgh Napier University. "In certain weeks, there was a 300 per cent increase in care home deaths in England, and 200 per cent in Scotland," he says. "We could say we were slightly better, but I wouldn't say a 200 per cent increase in deaths is something to shout about."

Then the paths taken by Scotland and England began to diverge.



JANE BARLOW/PA WIRE/PA IMAGES

Two days after the national lockdown began, Scotland's first minister Nicola Sturgeon created a scientific advisory group for Scotland to supplement the advice from the UK-wide Scientific Advisory Group for Emergencies. "That's probably when you started seeing more divergence," says Sridhar.

Scotland has been slower to relax lockdown than England and has done so in a step-by-step way, so that each

"We've stuck to our principles of old-fashioned, traditional, evidence-based contact tracing"

change's effects can be measured. This differs from England's rapid relaxation, says Sridhar.

Scotland has also been more successful at building up testing and contact tracing, without banking on the UK government's much-delayed app. "We've stuck to our principles of old-fashioned, traditional, evidence-based contact tracing," says Mark.

Two other factors have contributed to Scotland's relative success, says Sridhar. The first is clear messaging. On 10 May, the UK government changed its "stay at home" slogan to "stay alert", but Scotland stuck to the original line. It has since switched to "stay safe".

What's more, "there is a very high level of trust in the Scottish government and in Nicola Sturgeon's leadership", says Sridhar. According to YouGov, as of 1 May, 74 per cent of Scottish people approved of their government's handling of the pandemic and 71 per cent were confident in Nicola Sturgeon's decisions. In contrast, a June poll found that 50 per cent of British people disapproved of Johnson and only 43 per cent approved of him.

On 29 June, Scotland reported just 5 new cases, out of 815 for the UK as a whole, and announced no new covid-19-related deaths for the fourth day in a row. The nation could soon have days with no new

A handmade sign outside Ballachulish in Scotland's Highlands

confirmed cases. "Scotland's weeks away from that," says Sridhar. "England's months away."

Yet in practice, Scotland is unlikely to achieve full elimination in the near future, because it has a 154-kilometre border with England. "Many people cross that border every day," says Sridhar. "I think we will probably never get, without England's cooperation, to full elimination."

On 29 June, Sturgeon said that there are "no plans" to quarantine people who enter Scotland from other parts of the UK, but that the nation would need to "be able to consider all options" to stop the virus bouncing back if infection rates are different elsewhere in the country.

However, it should be possible for Scotland to keep the number of new cases very low – and perhaps encourage England to follow suit. ■

Testing

Southampton may test entire population weekly for coronavirus

Michael Le Page

A CITY in the UK is about to start testing thousands of people for the coronavirus each week, using saliva and a cheap, quick way of detecting the virus. If the initial trial in Southampton is successful, the aim is to test the city's entire population of 250,000 people every week to see if this can rapidly halt the virus' spread.

"We were told there were insoluble aspects, but they have been solved," says Keith Godfrey at the University of Southampton, who is helping organise the trial. "The government is certainly seriously interested."

It has been proposed that weekly testing of a country's entire population, regardless of whether people have symptoms, could quickly bring outbreaks to an end, with the resulting economic benefits far outweighing the costs of mass testing. Advocates of the approach include Julian Peto at the London School of Hygiene & Tropical Medicine and economist Paul Romer in the US.

On 10 April, an open letter to senior UK politicians and

scientific advisers signed by Godfrey, Peto, Romer and 31 others called for weekly universal testing to be trialled in a small city. The Southampton scheme is a first step towards this.

The initial study will begin with doctors and members of their households, and will be expanded to include council workers and university staff and students, with more than 10,000 tests being done each week.

It will look at whether testing saliva works as well as taking swabs from the nose and throat, the technique currently used to detect the coronavirus. The swab method is difficult, unpleasant and unreliable, producing many false negatives. By contrast, providing a saliva sample is as easy as spitting. People can do it at home and send samples off for testing, and some unpublished studies suggest that saliva testing is more reliable.

If this proves to be the case, it would be much easier to do mass testing. For instance, children attending school could be tested weekly. "Here we have a test that

would be acceptable to children," says Godfrey.

The study is also using a method of detecting the virus called RT-LAMP, which is much quicker and cheaper than the standard PCR method. It involves little more than adding a sample to a clear tube containing the necessary chemicals, putting it

Thousands of people are to be tested each week in Southampton, UK



PAUL WHITE AERIAL PHOTOGRAPHY/ALAMY

in a water bath to warm it and seeing if the colour changes.

"You don't need highly qualified staff," says Peto. "Anyone can stick something in a water bath."

Working with the National Health Service, the local council and the University of Southampton, Godfrey and his colleagues have also developed home saliva-collecting kits, ways of getting them to and from people and IT systems for quickly telling people their results by text. The trial is also integrated with the UK's contact-tracing system.

If the trial is successful, Godfrey wants to expand it to everyone in the city. "We are doing the pilot as a potential stepping stone to that," he says.

The idea of mass testing has been dismissed by many as unfeasible, says Peto. But between 14 and 24 May, China tested 9 million people in Wuhan. The tests identified around 300 people with asymptomatic infections and seem to have helped prevent a resurgence of covid-19 in the area. ■

Long-term impacts

Coronavirus has permanently scarred some people's lungs

PEOPLE infected with the coronavirus may be left with permanent lung damage.

The numbers of those affected aren't yet known, but estimates are as high as one in five people who needed intensive care treatment for covid-19.

Permanent damage sometimes occurs after other kinds of chest infections that can cause similar lung inflammation to the coronavirus, such as flu and

pneumonia. "We have always seen this before. What's different is the scale of this," says James Chalmers, a chest physician and adviser to the British Lung Foundation.

Previously, his clinic in Scotland would have seen post-infection scarring of the lungs once or twice a year, he says. "Now we are seeing dozens of patients coming through."

In a study in Italy, which was one of the first European countries to be hit by the coronavirus, doctors are scanning the lungs of people three months after they fell ill. Although the full results aren't yet in, Paolo Spagnolo at the University Hospital of Padua estimates that

15 to 20 per cent of those treated in intensive care at his hospital for covid-19 have scarring. "We have to be prepared in the future to manage these patients," he says.

In most people, the coronavirus causes only mild symptoms, but in some it leads to serious lung inflammation and an excess of immune signalling chemicals, leading to a complication called a cytokine storm. "If left unchecked, the inflammation starts to cause

20%

of people treated for severe covid-19 may have lung scarring

damage and scarring," says Chris Meadows, an intensive care doctor at Guy's and St Thomas' NHS Foundation Trust in London.

If someone is left with scarring, also known as fibrosis, there is no way to reverse it, says Chalmers. All people can do is try to improve their aerobic fitness to compensate.

Lung damage isn't confined to people who needed ventilation with covid-19, he says. "More severe covid means more likelihood of permanent damage, but I have got a couple of patients who were not on ventilators and have long-term complications." ■

Clare Wilson

The hope of immunity

Promising evidence suggests that we can develop at least some immunity to the coronavirus – but how strong is it and how long will it last? **Graham Lawton** reports

WHEN the novel pneumonia circulating in China was confirmed to be caused by a coronavirus, an already troubling situation suddenly got that bit worse. As a rule, coronaviruses don't produce a very strong "immune memory": the long-lasting response that allows our bodies to thwart a subsequent attack, and which makes vaccines possible. When reports emerged from Japan and China of people who had been given the all-clear catching the virus again, immunologists' worst fears seemed to be confirmed.

But seven months later, hopes are rising. There is no longer any serious doubt that our bodies can form an immune memory to the SARS-CoV-2 virus – although we still don't know how effective that memory will be. "That is the main outstanding question for covid-19," says Nicolas Vabret at the Icahn School of Medicine at Mount Sinai in New York.

"It's absolutely the right question to be asking now because so many things depend on it," says Paul Klennerman at the University of Oxford. That includes the prospect of developing vaccines, therapies and herd immunity (see box, right), but also decisions on whether to issue immunity passports to people who have recovered from the virus, and how and when to ease lockdown measures.

Immune memory can be an incredibly powerful and durable force. Immunologists like to tell the story of a measles epidemic on the Faroe Islands in 1846. When Danish doctor Peter Panum went to investigate, he discovered that the disease was raging, but also that 98 older people were immune to it. They turned out to be the survivors of the islands' previous outbreak in 1781. A single

encounter with the measles virus had endowed them with lifelong protection.

Other viruses, however, don't generate such a strong immune response, which can make them difficult to vaccinate against. Respiratory syncytial virus, for example, has thus far resisted all efforts to develop a vaccine. Other viruses elicit a moderate immune response and weak, brief memory. Vaccines for these viruses are possible, but often require regular boosters to maintain immunity.

Lines of defence

Until SARS-CoV-2 came along, immunologists would have placed coronaviruses at the recalcitrant end of the spectrum. There are four coronaviruses in general human circulation, all of which cause common colds. They do raise an immune response, but don't leave behind much of an immune memory. Within a year or so of clearing out such a cold virus, we are vulnerable to reinfection.

Protection against the SARS and MERS coronaviruses is somewhat better, lasting a few years, says Vabret. "Is SARS-CoV-2 going to look like MERS and SARS, with a few years of protection, or is it going to be like the others?"

There are two components to immune memory. The first is the antibody response, which is mediated by immune cells called B-cells. A healthy immune system maintains a huge repertoire of B-cells, each capable of producing a different antibody, which recognises and binds to particular molecules on the surface of pathogens called antigens.

When the immune system encounters a novel pathogen, any B-cells that happen to produce the right ones proliferate wildly, pumping out antibodies that



A laboratory in Russia tests for IgG antibodies to the coronavirus

neutralise the threat. Once the immune response gains the upper hand, a type of antibody called immunoglobulin G (IgG) becomes detectable in the blood.

After the pathogen is cleared, IgG continues to circulate in the bloodstream for weeks, months or even years, provided by long-lived B-cells in bone marrow. If these antibodies are potent enough, they are known as neutralising antibodies and provide an impenetrable shield to reinfection known as sterilising immunity.

Although antibody tests for coronavirus can indicate whether you have had the infection, a positive result doesn't necessarily mean you are immune or will be for a long time.

The other branch of immune memory also starts to sprout around the time that the pathogen is defeated. Some B-cells mature into memory B-cells, which take

90%
of people who had severe covid-19 still have high levels of antibodies two months later

40%
of people with asymptomatic cases have normal levels of antibodies after two months

60%
of patients have declining levels of antibodies by around three months



SERGEI KARPUKHINTASS VIA GETTY IMAGES

There are now promising signs that the coronavirus elicits both forms of immune memory. “I think it’s very likely that we will have effective immunity,” says Ashley St John at Duke-NUS Medical School in Singapore.

Antibody response

As for antibodies, we now know that IgG tends to appear in the bloodstream about five days after a person develops coronavirus symptoms. In a recent study of 624 people with mostly mild or moderate covid-19, a team from the Icahn School of Medicine found that all but three of them had the antibodies in their blood (medRxiv, doi.org/dt5t). Another study looked at 177 recovered patients who had been more seriously ill and found that more than 90 per cent had the antibodies, and still had high levels of them two months later (medRxiv, doi.org/d2nb).

This probably also means that memory B-cells are forming. “Antibody responses are usually a very good proxy for B-cell responses,” says St John.

up long-term residence in lymph nodes and the spleen. If the pathogen returns and isn’t instantly whacked by sterilising immunity – perhaps because the circulating IgG has dwindled or isn’t fully neutralising – these B-cells begin to proliferate again and quickly overwhelm it, often without any symptoms of illness.

Other immune cells, called T-cells, also contribute to immunity and are particularly important for viral infections. Helper T-cells coordinate immune attacks on infected cells, while killer T-cells do the attacking. Both types can become long-lived memory T-cells that settle into the lymphatic organs and tissues, ready to spring into action at the merest sniff of reinfection.

Together, the memory versions of B and T-cells provide functional immunity – they don’t prevent reinfection, they defeat it quickly.

As for T-cells, Klenerman and his colleagues have reported that all of a group of 42 people recovering from covid-19 generated “broad and strong” memory T-cell responses (bioRxiv, doi.org/ggz9n). “I think there’s a reasonable chance that people will develop some level of immune protection through antibody and T-cell responses,” he says.

But there are worries. One is that people who are infected but have no or only mild symptoms don’t generate a strong-enough response to lay down immune memories. Another is that even a strong immune response may dwindle quickly.

According to Klenerman, the strength of immune memory usually depends on the magnitude of the initial response. “The bigger the peak, the longer it will generally last, because everything is going to decay once the antigen has gone away.” This suggests that people who get mild or asymptomatic infections may remain vulnerable, he says.

One recent study in China seems to confirm that these are issues. It found that people who

were infected but asymptomatic had lower levels of IgG than symptomatic patients. In addition, their levels dropped quite quickly once they were virus-free, with 40 per cent back to normal after two months. The same study found that about 60 per cent of symptomatic patients also had declining IgG levels after two to three months (*Nature Medicine*, doi.org/gg26dx). “This is in line with some concerns that natural

“I think there’s a reasonable chance that people will develop some level of immune protection”

immunity to coronaviruses can be quite short-lived,” says Danny Altmann at Imperial College London.

The concentration of antibodies in the bloodstream doesn’t necessarily equate to how protected a person is, says St John. “You can have a lot of poor-quality antibodies, and that doesn’t help very much. Whereas if you have a few really good, high-quality antibodies, even if it’s a little bit lower concentration, those can be even more protective.”

On that front, there is also good news. A team at the Scripps Research Institute in California has isolated antibodies from the blood of recovered covid-19 patients and tested their potency. Of more than 1800 different antibodies, they found three super-potent neutralising antibodies (*Science*, doi.org/d2nc). If people with mild or asymptomatic cases are making these or similar antibodies, even in small quantities, they may well be protected, says St John.

Another hope is that people with mild infections might develop a newly discovered form of immune memory. When infections are confined ➤

Herd immunity

Despite evidence that people can develop at least some immunity to the coronavirus, the prospect of developing herd immunity without a vaccine remains slim.

Roughly two-thirds of a population would have to catch and recover from covid-19 to reach the herd immunity threshold, according to Haley Randolph and Luis Barreiro at the University of Chicago (Immunity, doi.org/ggwtm).

That would lead to some 30 million deaths from the virus

worldwide, including 6 million in China, a million in the US and 250,000 in the UK. On top of that, healthcare systems would probably be overwhelmed, resulting in additional deaths.

“Building up SARS-CoV-2 herd immunity through natural infection is theoretically possible,” say Randolph and Barreiro. “However, there is no straightforward, ethical path to reach this goal, as the societal consequences of achieving it are devastating.”

to the airways, they don't generate circulating antibodies, but they may still lead to the formation of memory cells. Immunologists have recently discovered that memory B and memory T-cells can both take up residence in mucosal membranes in the nose and lungs and can block a virus from re-entering the body. There is some evidence of this from a study of Swiss healthcare workers who were exposed to the virus but didn't fall ill (bioRxiv, doi.org/d2nd). Many had no antibodies circulating in their blood, but they did have antibodies in nasal swabs and tears.

Original sin

Yet more good news comes from the discovery that people who have never been infected with SARS-CoV-2 can nevertheless have memory cells that respond to it. Immunologists say these must be memories from previous infections with common cold viruses, even though the received wisdom is that these don't elicit a strong immune memory.

"There's some data for T-cells that some of the immune responses are cross-reactive," says Klenerman. "In other words, you've already got memory to something that's a bit like SARS-CoV-2 and the memory is boosted when you see it."

For example, a team led by Daniela Weiskopf at the La Jolla Institute for Immunology in California and Katharina Schmitz at Erasmus University Medical Center in the Netherlands analysed the T-cell responses of 10 people who had been hospitalised with severe covid-19. In keeping with other recent studies, they found that all 10 had helper T-cells that respond to the coronavirus, and eight had killer

T-cells (*Science Immunology*, doi.org/d2nf). But they also found T-cells that respond to SARS-CoV-2 in two out of 10 people who had never been infected with the virus. This, they conclude, is "indicative of cross-reactivity due to past infection with common cold coronaviruses".

"That will provide some level of protection, potentially," says Klenerman. "It's a hidden piece of the puzzle that needs working out, on both the T and B-cell side."

Cross-reactivity is also a positive

sign that we will develop some level of long-term immune response to SARS-CoV-2, says Vabret, although whether it will be strong enough to prevent infection isn't yet known.

It may also, paradoxically, make the disease worse, he says. In some other viral diseases, cross-reactive immunity can cause immune interference or what immunologists call "original antigenic sin". This is where the immune system falls back on its immune memory and fails to

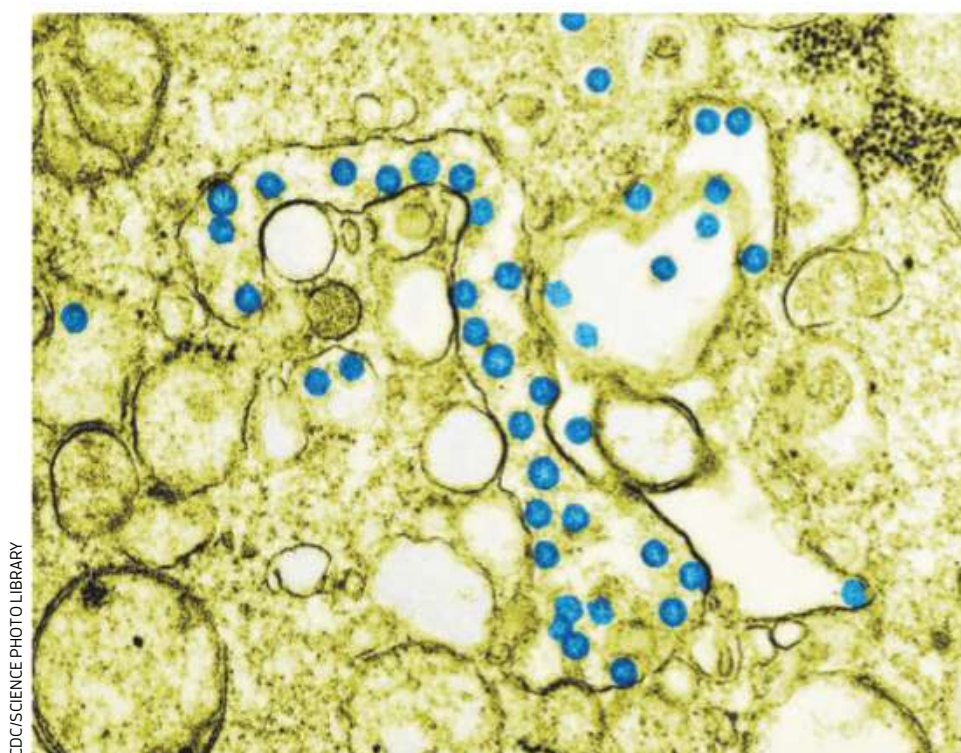
of reinfection," says Vabret.

Animal experiments point in the same direction. Early on in the pandemic, a team in China discovered that macaques can catch covid-19 but can't be reinfected 28 days after they recover (bioRxiv, doi.org/ggn8r8). That small study has since been replicated with more macaques and over five weeks (*Science*, doi.org/dwck). Intriguingly, the macaques seem to have been protected by functional immunity rather than sterilising immunity. "There's virtually complete resistance to disease and few clinical symptoms," says Altmann. "This seems a useful and clear answer. Of course, the big caveat is that this tells us about immunity at five weeks, whereas the answer we really want to know is about immunity at one or two years."

That remains the great unknown. The earliest survivors of covid-19 are only seven months into recovery, so knowing how long immunity will last is educated guesswork at best. "We have effective immunity," says St John. "The question is, for how long? That is something that we will have to continue to monitor."

"We will have some long-term immune response," says Vabret. "Will this immune response be sufficient to prevent reinfections? We don't know."

Even if our immune memory of the coronavirus is short-lived, it is still a boon because we can improve on it. Functional immunity opens the door to vaccines to induce and strengthen immunity. "The kind of immunity you get from a vaccine is not necessarily going to be the same as natural immunity," says Klenerman. "Vaccines are designed to generate really high levels of immune response. Hopefully we can do even better." ■



CDC/SCIENCE PHOTO LIBRARY

Coronavirus particles (in blue) as seen using an electron microscope

mount a new response despite never having seen that actual pathogen before. This is one potential reason why the disease is worse in older people, he says, because they have been exposed to many cold viruses over their lives and their bodies may be more likely to fall back on a previous response. Again, more research is needed to fully understand this.

As for those initial reports of people being reinfected by the coronavirus, they now appear to have been false positives. "There is no confirmed example

"Will this immune response be sufficient to prevent reinfections? We don't know"

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Psychology

New parents get a personality transplant

Jessica Hamzelou

HAVING a baby means new responsibilities, and parenthood should make people more mature – or so the theory goes. In fact, parents' personalities seem more likely to change in other ways. A study now hints that new mothers become more agreeable and extroverted, and new fathers become a little less extroverted, but more conscientious.

Eva Asselmann and Jule Specht at Humboldt University of Berlin studied socio-economic data collected from 19,875 people in Germany who have undergone yearly assessments since 1984. The volunteers took personality tests four times between 2002 and 2017 – during which 6891 of them became parents.

The assessments were designed to measure aspects of the “Big Five” model of personality, which captures a person's openness,

“New mothers may become more agreeable while new fathers tend to become less extroverted”

conscientiousness, extroversion, agreeableness and emotional stability.

A number of studies have shown that people in their 20s and 30s tend to become more agreeable, more emotionally stable and more conscientious. But it isn't clear why, says Manon van Scheppingen at Tilburg University in the Netherlands.

“It could be that it's genetics – that it's something that happens when the brain matures,” she says. “But we know that the environment plays a role.” Some have theorised that the change might be triggered by becoming



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A baby changes your life – and your personality

a parent, which often happens around this age.

“One might assume that the birth of a child relates to an increase in conscientiousness, agreeableness or emotional stability – but we did not find this,” says Asselmann.

Instead, it turned out that, in the year before the birth of their first child, would-be parents were more likely to be less open and more extroverted than non-parents. This suggests that they are less willing to try new and potentially risky experiences, but are social and assertive.

Both of these traits can change once a baby is born. People become even less open when they become parents, and this effect seems to last for at least three years. And while extroversion increases slightly on average after the birth, it declines in the following years.

Parenthood appears to affect men and women in different ways. While women generally seem to become more agreeable in the three years following

the arrival of a child, men seem to become more conscientious, suggesting they develop more self-control.

This might be a result of people falling into traditional stereotypes, with women spending more time with the baby and men feeling more pressure to provide financial support, say Asselmann and Specht (*European Journal of Personality*, doi.org/d2g9).

But neither gender showed an increase in emotional stability, which is thought to be a key indicator of maturity. The findings chime with other research, which suggests that new mothers experience a decline in conscientiousness or self-control after the birth of a child, says van Scheppingen.

New parents needn't worry, says van Scheppingen, their altered personalities aren't set in stone. Plenty of research shows that personality changes over the course of a person's life. And the changes that occur with parenthood might not last beyond a few years. “The changes are small,” she says. “It's not as if you become a completely different person.” ■

Physics

We have recorded the biggest ever lightning flash

Michael Marshall

THE largest lightning flash ever measured has been identified. More than twice the size of the previous record, it spanned 709 kilometres – about the distance from London to Geneva. A second flash has become the world's longest. It went on for 16.7 seconds, also doubling the previous record.

Until recently, lightning was primarily tracked using ground-based sensors. In 2017, the UN's World Meteorological Organization (WMO) used these to certify two world records: a lightning flash over Oklahoma in 2007 that spanned 321 kilometres and a 2012 flash over France lasting for 7.74 seconds.

However, in 2016, the US launched the world's first lightning-mapping satellite. This gives much more comprehensive coverage of Earth's surface. Two flashes detected from space have now been certified by the WMO as covering the longest distance and having the longest duration respectively.

The 709-kilometre flash happened on 31 October 2018 over southern Brazil and part of north-east Argentina. The satellite image revealed dozens of branches from the core flash.

On 4 March 2019, the 16.7-second flash occurred over northern Argentina. Both were cloud-to-cloud flashes and so didn't hit the ground (*Geophysical Research Letters*, doi.org/d2hn).

The flashes were so huge because of the powerful “mesoscale convective systems” that develop over the plains of South America, says Randall Cervený at Arizona State University. “They're aggregate individual superstorms that merge together into massive storms.”

Similar huge storms form over North America's Great Plains. Within the storm clouds, enormous electrical charges can build up, ultimately discharging over huge distances through the air. ■

Computing

Honeywell claims quantum record

Technology firm says it has built the most powerful quantum computer ever

Leah Crane

HONEYWELL, a company best known for making control systems for businesses and homes, says it has built the world's most powerful quantum computer. Other researchers are sceptical about the claim, but the firm says it is a step towards integrating quantum computing into its everyday operations.

The Honeywell computer's capabilities were measured using a metric invented by IBM called quantum volume. It takes into account the number of quantum bits – or qubits – the computer has, their error rate, how long the system can spend calculating before the qubits stop working and a few other key properties.

Measuring quantum volume involves running about 220 different algorithms on the computer, says Tony Uttley, the president of Honeywell Quantum Solutions. Honeywell's computer has a quantum volume of 64, twice as high as the next highest volume to be recorded, which was measured in an IBM quantum computer.

Like other quantum computers, this one may eventually be useful for calculations that deal with

huge amounts of data. "There are three classes of problems that we are focused on right now: optimisation, machine learning, and chemistry and material science," says Uttley. "We can do those problems shrunk down to a size that fits our quantum computer today and then, as we increase the quantum volume, we'll be able to do those problems on bigger scales."

However, this quantum computer isn't yet able to perform calculations that would give a

classical computer trouble, a feat called quantum supremacy, which was first claimed by Google last year. "It's cool that the company that made my thermostat is now building quantum computers, but claiming it's the most powerful one isn't really substantiated," says Ciarán Gilligan-Lee at University College London.

Google's Sycamore quantum

computer used 53 qubits to achieve quantum supremacy, while Honeywell's machine only has six qubits so far.

"We know that anything less than around 50 or 60 qubits can be simulated on a classical computer relatively easily," says Gilligan-Lee. "A six-qubit quantum computer can probably be simulated by your laptop, and [definitely by] a supercomputer."

Having the highest quantum volume may mean that Honeywell's qubits are remarkably accurate and can calculate for a long time, but it doesn't necessarily make it the most powerful quantum computer out there, he says.

Uttley admits that Honeywell's device can't yet do anything that is impossible for a classical computer, but he says that this is an important step towards quantum computers that are practically useful.

"Honeywell is in a lot of industries that we know are going to be profoundly impacted by quantum computing," says Uttley. "To be able to eventually insert this technology into our own work, we need to prepare now." ■

Inside the vacuum chamber in Honeywell's quantum computer



HONEYWELL INTERNATIONAL INC.

Microbiology

Drug-resistant bacteria lurk in home shower drains

ANTIBIOTIC-resistant bacteria have been found in more than three-quarters of the homes surveyed in a small study in Germany, and seem to thrive in showers.

Dirk Bockmühl at the Rhine-Waal University of Applied Sciences in Germany and his colleagues took swabs from shower drains,

dishwashers and washing machines in 54 private homes. They detected antibiotic-resistant bacteria in 82 per cent of the homes, mostly in shower drains.

A DNA analysis showed that there were twice as many antibiotic-resistance genes present in shower drains as in dishwashers, and 400 times more than in washing machines (bioRxiv, doi.org/d2hg).

Shower drains are attractive homes for bacteria because they are warm, humid environments

with a steady supply of nutrients, including dead skin cells and other organic matter washing from people's bodies, says Bockmühl.

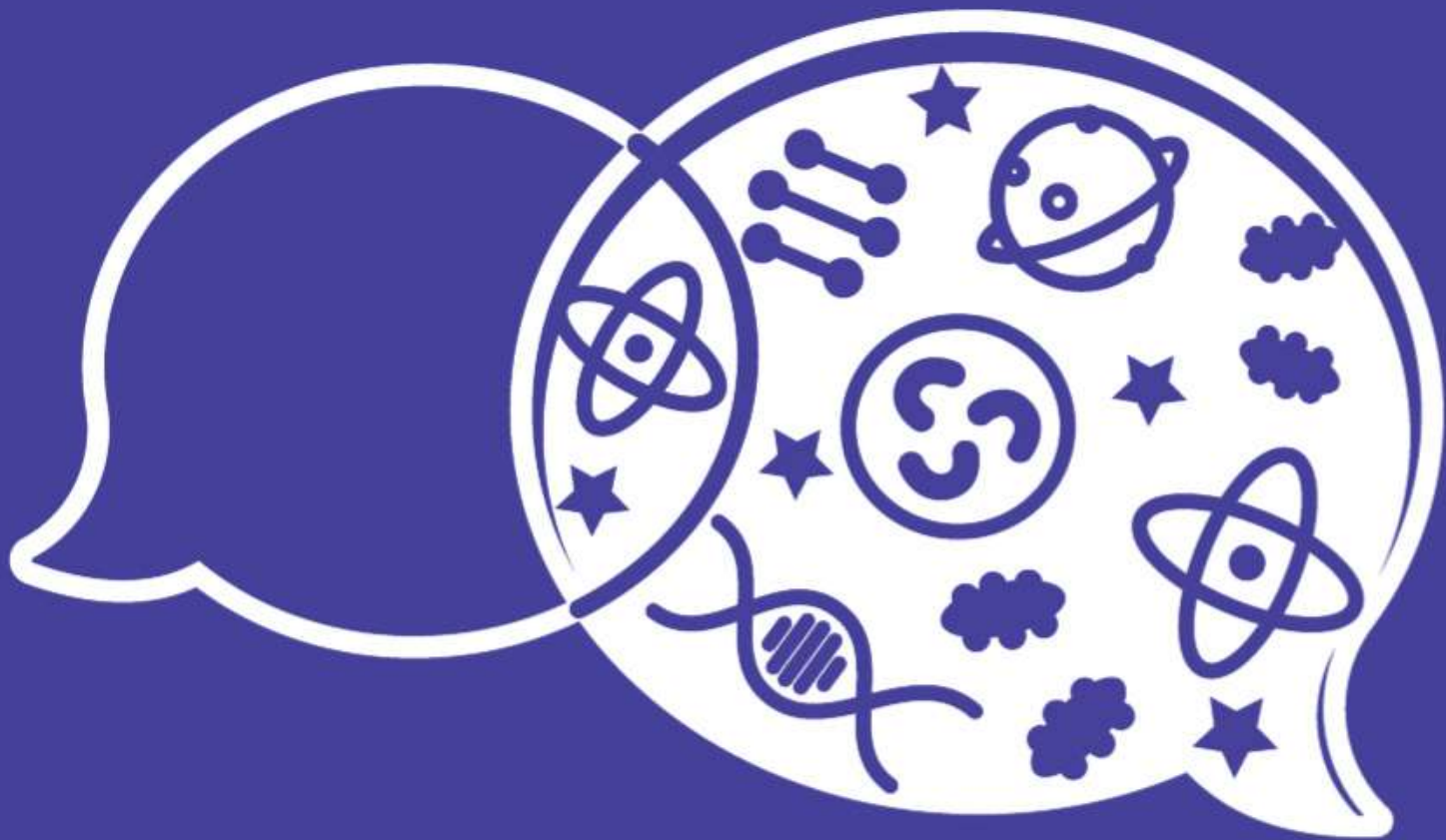
Bacteria in shower drains may develop antibiotic resistance because of repeated exposure to antibacterial agents that are found in soaps and cleaning products, he says.

82%

Proportion of homes in which drug-resistant bacteria were found

Even if the results from the study reflect an abundance of antibiotic-resistant bacteria in many homes around the world, most people shouldn't worry too much, says Bockmühl, "especially considering that we might come into contact with antibiotic-resistant bacteria quite often in everyday life". However, people who are more prone to infections – such as pregnant women and older people – should probably avoid touching shower drains, he says. ■

Alice Klein



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Military technology

US to test weapon that delivers electric shock at 100 metres

David Hambling

TASERS used by police officers to immobilise people with an electric shock only work at close range. Now, the US Marine Corps is testing a longer-range alternative: a projectile that releases electrode darts.

Called SPECTER, which stands for Small arms Pulsed Electronic Tetanization at Extended Range, it is being developed by Harkind Dynamics in Colorado with funding by the US Department of Defense's Joint Intermediate Force Capabilities Office (JIFCO). The makers say it can be fired from any 12-gauge shotgun and claim it can hit a human-sized target at "100-plus" metres.

David Law at JIFCO says electroshock devices are the only non-lethal weapon proven to stop determined opponents. Their use is controversial, though, and some studies cast doubt on their safety.

Tasers are handheld devices that contain batteries. They fire conducting wires to deliver a shock. This limits their range, to 8 metres in the case of the latest Taser X7 model. Electroshock projectiles that can reach further have been developed before – for example, the Sticky Shocker the 1990s. However, this could cause serious impact injury and was never deployed.

SPECTER reduces impact force with a braking system that uses radar to sense the distance to a person, and then deploys a parachute when it gets close. That halves the speed of the projectile, which fires three tethered electrode darts forward when it is 1 metre away.

The darts have sharp points to ensure contact with skin through clothes, and they deliver a novel electrical waveform that has less dramatic effects than other devices. The



MEDIA NEWS GROUP VIA GETTY IMAGES

makers say such shocks can make the person that is hit "lose posture" – that is, they may fall over.

The projectile can administer further shocks if it senses movement, or if it receives a manual instruction to do so. The person who is hit is supposed to be unable to move or attack. The control system adjusts the electric pulse to give the minimum necessary charge.

Though SPECTER is described as non-lethal, that doesn't mean there couldn't be risks to using it. Removing a barbed dart could cause damage, and "if you cause victims to fall over there is a known risk of head injury and bone fractures", says a

A parachute opens to slow SPECTER, an electroshock projectile



Electroshock guns may replace rubber bullet weapons (pictured)

spokesperson at Omega Research Foundation, a UK group that monitors security technology, including weapons.

"Less lethal projectiles are generally woefully inaccurate. I would like to see accuracy and consistency data for SPECTER and, crucially, high-speed footage to show consistent deployment of the parachute," the spokesperson says.

"If the parachute did not deploy, then you have the danger of direct impact with blunt trauma and possible penetration. If it hits the head, there is a risk of serious injury or death," the spokesperson says. Harkind Dynamics didn't respond to a request for comment on possible risks.

Patrick Wilcken at human rights group Amnesty International also stresses the need for testing before such systems are deployed.

The original request from the US Department of Defense asked Harkind to deliver 100 SPECTER rounds to the US Marine Corps. ■

Astronomy

Six alien moons may have been spotted

Leah Crane

OUR solar system is full of moons, more than 200 of them, but we have yet to definitively find one orbiting an exoplanet. Astronomers have now spotted six alien worlds that may have natural satellites.

Chris Fox and Paul Wiegert at Western University in Canada searched data from the Kepler space telescope for signals called transit timing variations. When a planet passes in front of its star, or transits, we see a dip in the star's light.

If the exoplanet orbits on its own, we see periodic dips in a precise pattern. But if its orbit is affected by the gravity of other objects – such as a moon or another planet – there are deviations from that pattern.

These are the transit timing variations. Fox and Wiegert found eight exoplanets with variations significant enough that they may indicate exomoons, but not so extreme that those moons would be big enough to see more directly.

They ran a series of simulations of the signals we would see if each of these exoplanets had either an

6

Possible exomoons found around planets beyond our solar system

exomoon or were accompanied by another exoplanet orbiting the same star. For two of the eight worlds, they found that additional planets explained the observations better, but they say that the other six could have moons (arxiv.org/abs/2006.12997).

These exomoons are far from proven, but if more information confirms them, finding an exomoon would be exciting, says Fox. "When we think about finding places to live in the universe and where we might find life, we typically think about planets first," he says. "But those planets could have moons that life could have evolved on." ■

Space

Nearby exoplanet may be ideal for life

JUST 11 light years away from Earth, two hot, rocky worlds orbit a small, red star. Their relative proximity makes them a promising study target, and there may be a third, habitable planet.

Sandra Jeffers at the University of Göttingen in Germany and her colleagues caught sight of the planets orbiting red dwarf star GJ 887 by watching for the wobbles in its light caused by the planets' gravitational pull.

These indicated that there were two hot planets circling close in to the star and suggested there might be a third orbiting further out (*Science*, doi.org/d2hj).

The third world, if it exists, could be within the star's habitable zone: the area where water on the surface of the planet could remain liquid instead of freezing or boiling away. **Leah Crane**



MAGDALENA LORDACHE/COVER IMAGES

Climate change

Hotter forecast could be due to clouds

NEW computer models have begun projecting a potentially much hotter future as carbon dioxide levels rise, and the reason seems to be to do with clouds.

The latest climate models show a much wider range for the future temperature than earlier ones, up from between 1.5°C and 4.5°C to between 1.8°C and 5.6°C. The estimates are for when the climate system comes into equilibrium after CO₂ levels have doubled.

The results imply that climate sensitivity – how much the planet will warm based on a given increase in CO₂ – is higher than previously thought. More realistic representation of clouds and aerosols seems to be the likely reason, according to Gerald Meehl at the US National Center for Atmospheric Research and his colleagues, who looked at 37 of the new models. **Adam Vaughan**

Zoology

Dogs were bred to pull our sleds millennia ago

THE 9500-year-old remains of a dog found on a remote island off Siberia are remarkably similar to living sled dogs in Greenland, genome sequencing has revealed. The discovery shows that people bred dogs for pulling sleds more than 10,000 years ago.

"We thought it would be a primitive dog, but it's a long way down the path to domestication," says Mikkel Sinding at the University of Copenhagen, Denmark. "That was quite sensational."

Excavations of ancient human settlements on Zhokhov Island north of Siberia have revealed the remains of numerous dogs and what look like dog sleds. "It's the first place in history where you

have intense dog use," says Sinding.

His team sequenced the best-preserved dog found on Zhokhov, along with a 33,000-year-old Siberian wolf and 10 living sled dogs from different places in Greenland, and compared their genomes with each other and with other dog and wolf genomes.

The results show that modern sled dogs in Greenland, whose ancestors were taken there by Inuit people around 850 years ago, are more closely related to the 9500-year-old Zhokhov dog than to other kinds of dogs or to wolves (*Science*, doi.org/d2g6).

"It's largely the same dogs doing the same thing," says Sinding.

While the Zhokhov finds are the earliest clear evidence of dogs pulling sleds, ivory artefacts that may have been used to attach reins to sleds have been found elsewhere. Some are 12,000 years old.

The genomes also show that sled dogs haven't acquired any DNA from wolves in the past 9500 years. **Michael Le Page**

Really brief



CHRISTOPHER FURLONG/GETTY IMAGES

Lockdown cleans up UK air pollution

The UK-wide coronavirus lockdown cut nitrogen dioxide levels. Between the start of the lockdown on 23 March through to 28 April, the average daily concentration dropped to less than 5 micrograms per cubic metre – the lowest in a decade (arxiv.org/abs/2006.10785).

Aerial wiggle helps snakes glide

Snakes undulate their bodies to propel themselves on land or through water, but why certain flying snake species do so in the air was unclear. Researchers have now found that undulation helps such snakes stabilise their bodies, enabling them to glide further (*Nature Physics*, DOI: 10.1038/s41567-020-0935-4).

Genetic mutations may predict lifespan

A study of 61 men and 61 women – and their children and grandchildren – found that those with more genetic mutations were twice as likely to die of any cause over the study period than those with the fewest, who had an average survival advantage of almost five years (*Scientific Reports*, doi.org/d2gp).



Launchpad

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**Leah
Crane**

Signal Boost

Welcome to our Signal Boost project. In these difficult times, we are offering charitable organisations the chance to take out a page in *New Scientist*, free of charge, so that they can get their message out to a global audience. Today, a message from **Wild Futures**



Emergency appeal. Can you help?

Wild Futures is the UK primate welfare and conservation charity, rescuing, campaigning, educating and providing sanctuary to primates in need.

Sixty percent of all primate species face extinction due to human activity; habitat loss, climate change, the bush meat and primate pet trades all contribute to this challenge to their survival.

Founded in 1964, The Wild Futures Monkey Sanctuary in Cornwall, UK, was the first of its kind in the world. Our innovative welfare management practices, exceptional levels of care for monkeys traumatised by the primate pet trade and our internationally recognised training and education programmes mean that our sanctuary is the only one in Europe to be accredited by the Global Federation of Animal Sanctuaries. The charity's commitment to education and skill-sharing is reflected in our board membership of the European Alliance of Rescue Centres and Sanctuaries (EARS).

Wild Futures' holistic ethos is illustrated by its commitment to maintaining wildlife habitats on the Sanctuary site whilst applying sustainable

environmental policies from energy use, purchase power to recycling.

Providing support to overseas projects in habitat countries with practical assistance, skills sharing, staff secondment, funding and advice are all part of the vital work of the charity in its aim to protect primates and habitats worldwide.

Covid-19 is causing devastation all across the world and like many others we are struggling as a result of this pandemic. We are facing one of our toughest years to date.

The Sanctuary is home to 40 monkeys rescued from situations of abuse and neglect from the UK primate pet trade. As fellow primates they may be very susceptible to Covid-19; many have heart disease and diabetes as a result of their lives as pets, raising the risks further. Wild Futures is taking every precaution to protect the monkeys, splitting the

team on and off site and isolating the Sanctuary. Our main priority is to make sure the monkeys have the food and the medicines they need along with continued care.

However, overnight the charity lost its main sources of income from visitors, education, volunteer and training programmes. This has huge financial ramifications. We are facing troubling times.

We are appealing for emergency help to get us through this uncertain time.

Despite the challenges, we will continue caring for the rescued monkeys in our care and continue to promote primate welfare and conservation worldwide.

Please donate today www.wildfutures.org/donate and follow us on Facebook for updates.

Wild Futures, The Monkey Sanctuary, Looe, Cornwall, PL13 1NZ. Tel: +44 (0) 1503 262532

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If you are a charitable organisation working in science, medicine, technology, education or conservation, and would like to find out more about this project contact Chris Martin on chris.martin@newscientist.com

Letters

On the trail of the perfect contact-tracing app for the coronavirus **p22**

Culture

The search for life on Mars has been disappointing, but it isn't over yet **p24**

Culture

There are reasons for hope with gender discrimination in science **p25**

Aperture

Foraging for plastic in the polluted swamps of Lake Victoria **p28**



Annalee Newitz is a science journalist and author. Their latest novel is *The Future of Another Timeline* and they are the co-host of the Hugo-nominated podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is techsploitation.com

Annalee's week

What I'm reading

P. Djèli Clark's novella Ring Shout, about how monsters took over the Ku Klux Klan in 1922.

What I'm watching

A documentary called Coded Bias about how algorithms reproduce social inequalities.

What I'm working on

A story about what will happen to public transit after the pandemic.

This column appears monthly. Up next week: James Wong

Columnist

Digital disobedience

Unusual methods of online protest have sprung up recently, and it has become harder to tell what's real and what's not, says **Annalee Newitz**

AN UNEXPECTED form of protest has exploded across social media. Fans of Korean pop music, K-pop, have been adding their voices to the Black Lives Matter protests by "occupying" digital spaces with a flood of adorable music videos. Already, they have disrupted police surveillance, US president Donald Trump's re-election bid and a meeting of white supremacists on Twitter.

It all started when the large and enthusiastic community of K-pop fans in the US heard that police in Dallas, Texas, were asking concerned citizens to send in videos of "illegal activity from the protests". Sick of police targeting peaceful protesters, fans spread the word among their ranks that everyone should flood the Dallas police app with their favourite gifs and videos. It worked. Soon, the police were watching clips from bands like BTS and gifs from the game *Animal Crossing*. Eventually, the reporting system crashed.

Thrilled with their efforts, fans used similar tactics with a white supremacist hashtag on Twitter. Many groups form ad hoc "public squares" on Twitter by using hashtags, like #blacklivesmatter, to organise and share information. The fans' goal was to take over a white supremacist hashtag by posting nothing but K-pop content to hinder racists from speaking with each other. Within hours, they had tweeted so much that the hashtag became completely

useless – unless your jam is fighting about the merits of different BTS songs.

As their coup de grâce, the fans targeted Trump's re-election campaign, snapping up free tickets to his Oklahoma rally. They claimed to have reserved nearly a million, leading the Trump campaign to build an extra stage and proclaim there would be overflow seating only. Just 7000 or so people showed up.

"In the world of hashtags, it's hard to separate grassroots actions from state-sponsored interference"

It is interesting to compare these protests with a related form of hashtag skullduggery that took place during the Washington DC protests after George Floyd's death at the hands of police. In the early morning on 1 June, several newly created Twitter accounts used the hashtag #dcblackout to spread the rumour that the government had ordered a blackout of the city overnight, shutting down phones and internet access to stop news of the uprisings. Even though many people were reporting live from their phones during the supposed blackout, the rumour popped on Twitter and beyond. Half-a-million accounts retweeted the hashtag in just 9 hours.

And then the rabbit hole went

deeper. A second wave of rumours began to spread on the hashtag, coming from hacked accounts and bots. Suspiciously, all these tweets used the exact same wording to deny the blackout had happened. The #dcblackout tweets and counter-tweets seemed perfectly designed to inspire conspiracy theories, which they have – even after countless sources, from electrical grid experts to eyewitnesses, demonstrated that the blackout hadn't occurred.

Harvard University's Joan Donovan said that the #dcblackout cycle of hashtag manipulation felt like carefully targeted propaganda, intended to foster confusion and fear. Perhaps it came from foreign actors, or some group closer to home. Either way, the result distracted from the real issues underlying the protests. Unlike the K-pop hashtag protests, which were chaotic and spontaneous, the #dcblackout tweets felt as crafted as a Thomas Pynchon novel.

In the world of hashtags, it's hard to separate grassroots actions from state-sponsored interference. In fact, some of the first accounts to spread the #dcblackout rumour were ones that normally spout K-pop news. These days, media literacy requires us to spend lots of time rescuing legitimate information from an endless avalanche of randomness. The greatest propaganda weapon in the social media age might be noise. ■

Editor's pick

On the trail of the perfect contact-tracing app

6 June, p 7

From Charlie Wartnaby,
Cambridge, UK

Given the difficulties with finding an effective phone app to help with coronavirus contact tracing in the UK, I have an idea that may help. A difficulty is obtaining a reliable range measurement between two people using the Bluetooth signals of their phones. But, in 2016, you reported on ultrasonic data transfer using cellphones.

My simple suggestion is that once rough proximity is established via Bluetooth, one phone should send an ultrasonic "ping" from its speaker, picked up by the mic of the other, which then replies with an accurately defined delay. The round-trip time then gives a very good distance measurement simply based on the speed of sound. Also, it wouldn't misleadingly flag a nearby person who is actually on the other side of a wall or screen, which Bluetooth alone might.

I just need to get this idea within 2 metres of the app developers.

What happens when we move to 1-metre spacing?

30 May, p 10

From Peter Borrow, Amersham,
Buckinghamshire, UK

As a scientist, I tend to see inverse laws all over the place, and am wondering how they feature when it comes to the transmission risk of the coronavirus.

As a first approximation, does the risk of virus transmission with social distance follow an inverse, an inverse square or an inverse cube relationship? If we double the distance, does the risk halve, quarter or become one-eighth?

It would be good to know, as my observation in supermarkets is that most people's idea of 2-metre social distancing falls short of that, so if we reduce it to 1 metre (as we are about to in England) will it become even less than that?

The long, long wait for nuclear fusion

13 June, p 30

From James Edmondson,
Ilchester, Somerset, UK

Your coverage of developments that could bring us closer to controllable, sustainable fusion power reminded me that our attempt to develop this energy source is undoubtedly the best example of Hofstadter's law. This states: "It always takes longer than you expect, even when you take into account Hofstadter's law."

From Brian Pollard,
North Hill, Cornwall, UK

The problem with fusion power is that both major designs now in operation – laser confinement and toroidal plasma containment – are far from ideal for a practical power plant. In order to generate fusion power continually and remove the heat generated, a third, and completely different, design, yet to be envisaged, will be required.

I would say that if this were akin to trying to build a Boeing 747, fusion power is at the stage of a hot-air balloon still tethered to the ground. Fusion power is a very long way indeed from being a useful source of power.

Reasons why our reality probably isn't simulated

6 June, p 46

From Guy Cox, Sydney, Australia

Nick Bostrom's reprinted article, which discussed the idea that our reality may be a simulation, doesn't begin promisingly when he says "we are made of the same stuff as mud". Well, not so much – the essential components of mud are alumino-silicate clay minerals and these play no part in the mammalian body.

I take it that the article was

written, if not as a joke, then at least as a *jeu d'esprit* to provoke discussion, so I won't go through all the logical inconsistencies. But I will point to the pachyderm on the premises. No civilisation living on a planet in a solar system (and we don't know of anywhere else a civilisation could live) could obtain enough energy to run such a simulation, at least not without destroying their solar system.

So we can be pretty confident we aren't living in a simulation.

From Toby Pereira,
Rayne, Essex, UK

It would be impossible to simulate a reality as detailed as the one we are in (at least in real time) because to do so would require all the resources that the universe contains.

It is still possible to have a simulation of sorts requiring less resources by concentrating more of its power on the simulated beings themselves and less on the rest of the detail of the simulated universe. But it is likely that this would give these beings a rather impoverished existence without much of a detailed outside world, and there is no reason to suggest that we are in such a simulation.

Maybe AI will help us control the weather

Letters, 6 June

From Michael Assuras,
London, Ontario, Canada

I was intrigued by the idea from Dwight Hines that artificial intelligence could be used to develop a better lie detector based on analysis of speech. A more far-fetched idea came to me: would it be possible to train an AI on satellite images and other meteorological data to predict hurricanes before they happen or before they get out of control?

I am no expert on hurricanes, but would it be conceivable to stop a potential hurricane at a very early stage, perhaps with an injection of cool air from an aircraft? The possibilities with AI are endless and exciting, but maybe this application is too unrealistic to reach fruition.

Are we born good or are we made that way?

13 June, p 26

From Peter Slessenger,
Reading, Berkshire, UK

Simon Ings is right to tell readers that Rutger Bregman's examples in his book *Humankind: A hopeful history* are cherry-picked to back the hypothesis that our species is innately good rather than bad.

In particular, the enviable record of low reoffending among those released from high-security Halden prison in Norway might have something to do with prisoners being returned to Norwegian society, rather than a society with high levels of inequality, deprivation and racism, for example the US.

Consciousness could be another aether

Letters, 6 June

From Ólafur Jónsson,
Mendrisio, Switzerland

I do enjoy the frequent letters and occasional articles on the subject of consciousness. I am, however, bewildered by how the concept is defined. It seems to me that no two people can agree on what it is they are trying to describe.

Maybe because I have learned a spattering of languages in my life, I'm used to trying to guess a word's meaning from its context, and the context seems to me to vary significantly in writing on the matter of consciousness. I wonder if the search for it is like that for the luminiferous aether, the proposed medium that would allow light waves to move through space. What reason do we have to assume consciousness exists, however much we "feel" it must? ■



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Up close with the Red Planet

We once thought Mars had canals built by an advanced society. We have come a long way since then and there is still much to discover, finds **Leah Crane**



Book

The Sirens of Mars: Searching for life on another world

Sarah Stewart Johnson
Allen Lane

IF YOU look up on a clear night, you might spot a light brighter than all the others, not twinkling like a star, but floating serene and reddish-tinged in the sky. Across history, many have gazed at Mars and imagined what its distant shores might hold. Some have even sent spacecraft up there to find out.

In her book *The Sirens of Mars*, Sarah Stewart Johnson tells the story of the Red Planet and those who have sought to understand it, from Herodotus and Euclid to NASA and its Curiosity and Perseverance rovers, with the author herself slotted in between.

The tale begins before Mars was even understood to be a place, when it was just a light in the sky. It then moves on to when scientists thought that Mars could be truly the twin of Earth, when apparent lines on its surface were taken to be the canals of an advanced society. Even after discovering they weren't canals, people still thought they could be signs of vegetation, the signature of a green and thriving planet.

At the point Stewart Johnson reaches the first space missions to fly by Mars and their failures to spot any obvious signs of life, the disappointment is palpable. The narrative feels as if it is building towards a big revelation, maybe even the discovery of living organisms on Mars. Those who have studied the planet for a long time know intimately the roller coaster of emotion it has caused.



NASA/JPL-CALTECH

Stewart Johnson has made Mars her life's work. She is from a space-loving family, making her career choice seem inevitable. The book is part memoir, part history, part education, and the three flow together so smoothly you might not even realise how much you are learning about Mars.

"Mars may not be quite as arid and dead as we once thought, but rather it has water hiding everywhere"

At one point, she describes crater walls as "reveal[ing] layers that had been stacked like the pages of a closed book, one moment in time pressed close against the next". She manages to press moments in time together as closely as the sedimentary rocks on Mars, revealing its history just as the rocks do.

As much as that history contains many disappointments,

from the revelation that the canals of Mars aren't real to the understanding that there is unlikely to be life on the surface, it is also optimistic. There are many joyful moments, such as when scientists realised that Mars might not be quite as arid and dead as we once thought, but rather it has water hiding everywhere.

Those moments are what propel the story forward and what drives Stewart Johnson to keep travelling to some of the most extreme and barren environments on Earth to grasp at the possibility that there may yet be life on Mars that looks nothing like it does here on Earth. "We are still struggling to contend with the truly alien, to recognize and interpret signs of 'life as we don't know it'," she writes.

The Sirens of Mars comes at an exciting time: Mars researchers have more information now than at any other point in history, and NASA's Perseverance rover, scheduled to launch this month, will surely bring a wave of

NASA's Perseverance rover will soon look for signs of life on Mars

discoveries when it collects rock and soil samples in its search for signs of ancient life. Yet as the interest in Mars grows, with many nations and companies working on missions to its surface, researchers' efforts to understand it become increasingly urgent.

As Stewart Johnson writes: "The next decades are thus critically important for the search for life because the window to explore an untrammelled planet – a pristine record of the past – is closing."

In the end, the book tells you what anybody who has studied science learns as they move from one school year to the next: the more we know, the clearer it is that what we thought we knew before was wrong. However, as Stewart Johnson so clearly describes, the journey of understanding where we were wrong propels us ever forward to explore. ■

The science shift

Picture a Scientist shines a light on gender discrimination in science – and also finds reasons to be hopeful, says **Simon Ings**



Film

Picture a Scientist

Sharon Shattuck and Ian Cheney
Virtual screenings from 26 June

WHAT is it about the institutions of science that encourages bullying and sexism? That pushes a young geologist down an Antarctic hillside? That tells a Black chemist to straighten her hair before applying for a job? That takes vital equipment from the tiny, ill-appointed lab of a promising researcher? *Picture a Scientist* follows the careers of three women and pinpoints where the field has let them down.

Women disproportionately drop out of academia. In 2018, women were awarded 50 per cent of the bachelor's degrees in science and engineering in the US, but only 36 per cent of postdocs that year were female. Small wonder, considering the experiences of the three women at the heart of this film.

As a PhD student at Boston University on her first research trip to Antarctica, geologist Jane Willenbring was insulted, bullied and physically abused by her supervisor. In the film, she deplores a culture that benefits those who put up and shut up. PhD students are all too aware that an ill-disposed supervisor can foreclose all avenues of professional advancement. It pays them, therefore, to be tolerant of their supervisor's "quirks" – to see no evil in them, and speak no evil of them. In this dynamic of patron and client, the opportunities for abuse are rife.

The film also features Raychelle Burks, a chemist at American University in Washington DC, and Nancy Hopkins, a geneticist at the

Massachusetts Institute of Technology (MIT). The trio are very successful, despite their struggles. Willenbring, now at the Scripps Institution of Oceanography in California, studies how Earth's crust responds to climate change. Burks develops cheap, easy forensic tests for war zones and disaster relief. Hopkins studies cancer.

Their stories bring some measure of hope to the film: for instance,

"Accomplished scientists have to spend so much time fighting for their right to come to work at all"

Willenbring eventually won a lawsuit against her former supervisor, who was dismissed from the university.

All three are passionate advocates for the welfare of women in science, but insist they would much rather have been allowed to do their jobs. "The time-suck is killing," says Burks, who has been regularly mistaken for a member of the cleaning staff and challenged when using the staff car park. One is left with a profound

sense of how much good science may have been lost, when accomplished scientists have to spend so much time fighting for their right to come to work at all.

Throughout her career, Hopkins's groundbreaking work on zebrafish was disrupted by colleagues who seemed to think they needed her equipment more than she did. She also identified institutional bias. When Hopkins tried to convince MIT that female staff were being crammed into the university's smallest laboratories, she was met with incredulity.

There was no decree stating women should be treated this way, so managers were reluctant to even consider the evidence Hopkins presented. She feared that she would gain a reputation for being "difficult". After a five-year study, MIT and its provost Robert Brown eventually decided in 1999 to set about correcting the examples of sexual discrimination Hopkins and her colleagues had brought to light.

All this effort took time away from Hopkins's research. "Such a waste of time and energy," she says, "when all you wanted was to be a scientist." ■



UPRISING LLC

Nancy Hopkins has worked to improve conditions for women in academia

Don't miss



Play

Duet-2 is a game from arts collective Invisible Flock on iOS and Android in which pairs of strangers establish a real, though mysterious, connection. Answer a question a day and share glimpses of your life with someone new.



Read

Sophie's Planet is a book containing a series of letters that climatologist James Hansen wrote to his granddaughter Sophie, revealing how, as her generation grows, they can – and must – fight to preserve non-human life on Earth.



Watch

Warrior Nun, streaming now on Netflix, is set in a world where Catholic superheroes battle demons. It is an oddly plausible set-up, based on over a quarter-century of Ben Dunn's comic book tales of good versus evil.

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Our expert panel on how researchers around the world are racing to understand the virus and prevent future outbreaks





Murky waters



Photographer **Frédéric Noy**
Agency **Panos Pictures**

FORAGING in the swamps of Lake Victoria in East Africa, this man makes a living by selling old plastic bags to recyclers.

Wetland areas usually purify the water in the lake and run-off by filtering it. However, a growing amount of pollution is disrupting this process. For instance, blue dye from these plastic bags will eventually seep into the water.

This isn't the only problem besetting Lake Victoria, which is more than 300 kilometres wide and the largest by area in Africa. Climate change is causing it to steadily dry up, while cities in the bordering nations of Kenya, Tanzania and Uganda are dumping untreated waste into its waters. One million tonnes of fish are harvested from the lake each year. The pressure on its stocks is being made worse due to poaching and overfishing.

It is now down to governments to devise plans to preserve Lake Victoria while meeting the needs of the more than 30 million people whose livelihoods depend on its resources.

"In the next 50 years, if nothing radical is done, Lake Victoria will be dead because of what we are pouring into it," says Peter Anyang' Nyong'o, governor of Kenya's Kisumu county. ■

Gege Li

Dominate or influence?

Today's leaders are very different from those who led humanity for most of its existence.

Emma Young finds out why

DONALD TRUMP in the US and Jacinda Ardern in New Zealand. Vladimir Putin in Russia and Sanna Marin in Finland. It is hard to imagine more drastically different political figures. Yet each of these individuals has reached the highest office in their country. Given the vast differences in their personal qualities, behaviour and rhetoric, can we ever understand what makes for a successful leader? How is it that Trump, Ardern, Putin and Marin can all become leaders of their nations?

If you have had any exposure to business leadership theories, you may see a pattern here. Many identify two main ways that leaders exert their influence over groups.

These dichotomies go by names such as democratic versus autocratic, participative versus directive and personalised versus positional. This sort of analysis may be helpful in characterising leadership styles, but it can only take us so far in understanding why we have the leaders we do. Now, an idea emerging from evolutionary biology promises to do much more.

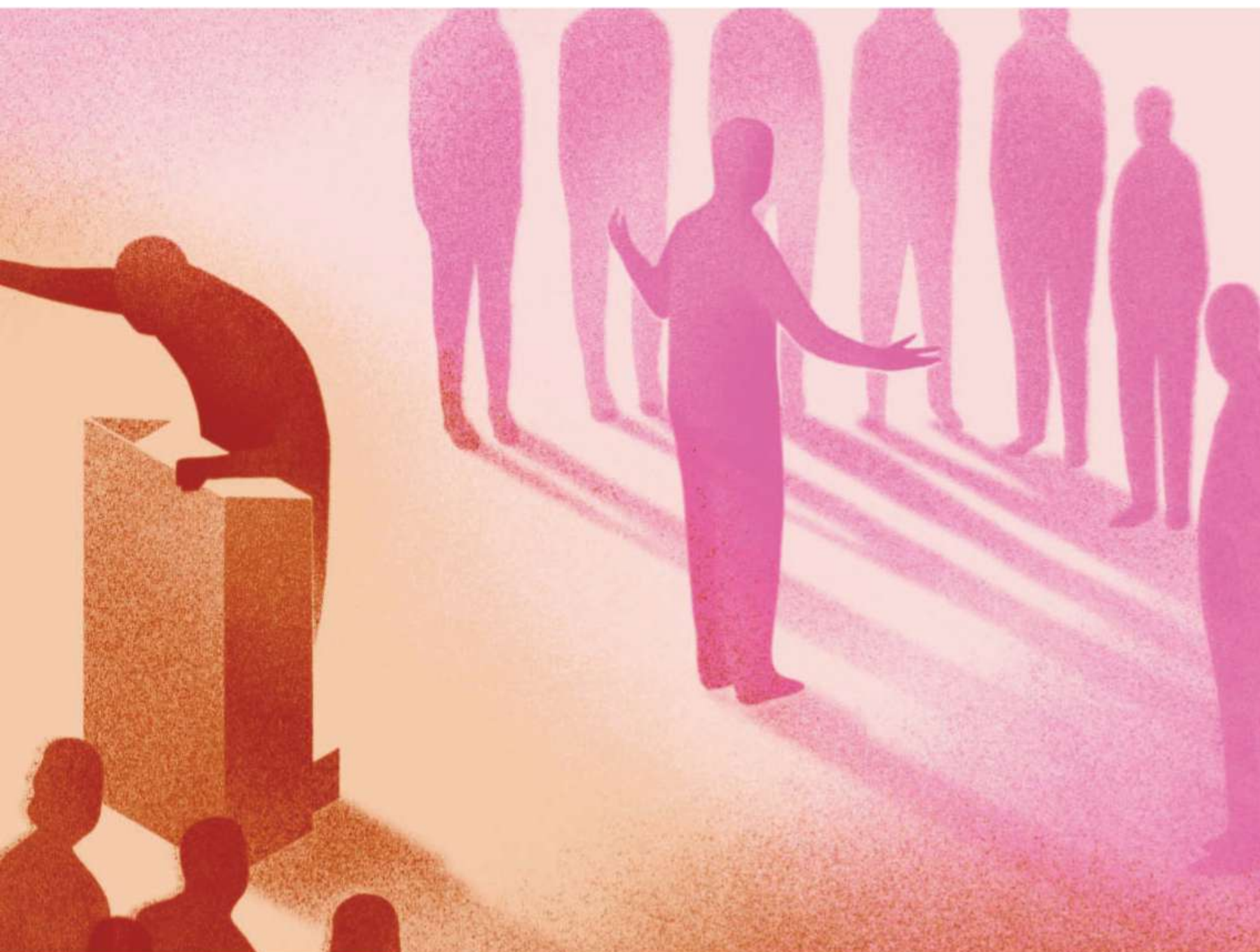
This approach connects the two distinct leadership styles with deeper human drives and motivations. Its proponents argue that through this perspective, we can explain a lot about the state of the world today, from the US-China trade war to the success of countries such as New Zealand, Germany

and Taiwan in responding to covid-19, and from Boris Johnson's victory in last year's UK general election to the under-representation of women in boardrooms. Some believe this model can even predict the outcome of the forthcoming US presidential election. Can they be right?

Evolutionary biologists call the two styles of leadership "dominance" and "prestige". A prestige leader influences people through their superior personal attributes, such as knowledge, wisdom and vision. These leaders may also be charismatic and use their skill at rhetoric to win over followers: think of Jesus or Confucius. Or, for a more contemporary case, take the German chancellor Angela

DANIEL STOLLE





“Prestige leaders use their superior personal attributes to influence”

Merkel. Women aren't restricted to prestige leadership alone, but it is thought by some that female leaders generally operate this way because women's responsibilities for childcare and food-gathering throughout most of human history have left them with an “evolved psychology” that is more cooperative, in general, than men's. At least, that's how prestige leadership is depicted by Mark van Vugt at Vrije University in Amsterdam, the Netherlands, and Jennifer Smith at Mills College in Oakland, California, in a paper published last year that sets out this evolutionary model.

They say that dominance leaders, in contrast, exert influence by demanding

support, instilling fear in would-be dissenters and threatening sanctions for anyone who fails to toe the line. Think of any Machiavellian ruler, from Attila the Hun to Stalin. There are also plenty of examples of milder dominance leaders around today, including Trump, Putin, China's Xi Jinping and Jair Bolsonaro in Brazil. Being physically imposing is often key to their approach, so such leaders are almost always men, according to the dominance/prestige model.

Van Vugt and Smith point to a range of evidence indicating that these two leadership styles are rooted in biology. Personality tests of group leaders reveal that those adopting a dominance style score higher ➤

“Dominance leaders exert influence by demanding support and instilling fear”

for aggression, disagreeableness and psychopathy (a collection of traits including a lack of empathy and remorse), whereas prestige leaders are strong on agreeableness and conscientiousness. Dominance leaders, especially male ones, tend to have relatively high testosterone levels, which manifest in more masculinised faces and bigger bodies. In contrast, some studies indicate that prestige leaders may have higher levels of the prosocial hormone oxytocin. There are also differences in the non-verbal displays people use to signal their status to others. Prestige leaders smile more, for example, and dominance leaders have more expansive bodily gestures.

What's more, it would appear that these two leadership styles evolved far before our species. They have been charted in a wide variety of mammals, from meerkats and hyenas to killer whales and elephants, and are particularly apparent in the behaviour of our closest relatives, chimpanzees and bonobos.

In bonobo societies, females take the lead in resolving disputes. “The prestige style of leadership by females within these groups results in social lives with very little conflict,” says Smith, who is a behavioural ecologist. By contrast, chimps are led by alpha males that rely primarily on dominance leadership, and there is far more conflict within and between chimp groups than among bonobos.

Prehistoric influencers

There are some hints that our species is naturally more bonobo-like than chimp-like. Anthropologists have long noted that dominance leaders are relatively rare within modern hunter-gatherer societies, which live as people have done for most of human existence. Van Vugt and Smith argue that until quite recently, in evolutionary terms, people favoured prestige leaders and actively selected against dominance ones. But if that's

the case, why do so many modern leaders adopt a dominance style?

The key, they say, isn't biological evolution, but cultural evolution. In traditional, small-scale societies, everybody knew each other and most people were related. This changed when urbanisation began, around 6000 years ago. A shift towards more complex, hierarchical, larger-scale societies of unrelated strangers would inevitably have resulted in some individuals trying to game the system. Dominance leaders are more willing to punish such free-riders, while also offering to protect their group from outsiders. So the new social set-up would have favoured them.

These influences on leadership are even more pronounced in the modern, globalised world. Nationalistic ideologies often portray immigrants as scroungers, for example. Global competition also makes it easy to perceive other nations as threatening. For example, Trump and many of his supporters view China as an economic threat, North Korea and Iran as military threats and Russia as an existential threat. The coronavirus pandemic just adds to this. Van Vugt, a psychologist, has found that infectious diseases can cultivate prejudice against outsiders, heightening perceptions of external threats. Trump has played on this, recently referring to the covid-19 pathogen as the “Kung flu”.

Of course, it isn't always black and white. Politicians tend to use a combination of both prestige and dominance to achieve power. Trump's talent at doing deals, making money and getting things done were lionised by his presidential campaign team. And, as Jane Mansbridge at Harvard University observes, Xi rose through a system that rewards meritocratic excellence, as well as ruthless political savvy. Modern humans haven't shifted to crave dominance alone, stresses van Vugt. We still want prestige in our leaders and look for signs of competence and ability.

Still, the model predicts that voters favour more dominant leaders when they feel threatened. This might help explain why Boris Johnson beat Jeremy Corbyn in the UK general election last year, when the country was deeply divided over Brexit. It also makes



Females take the lead in bonobo groups and rule by persuasion rather than intimidation

How to rally followers

There is no leader without followers. So, to understand leadership, you need to look at group dynamics and how social identity is managed, says Stephen Reicher at the University of St Andrews, UK. With that in mind, he and his colleagues have identified four dimensions to effective leadership.

First, a leader must be seen as one of the group. Second, they must act for the group above all other interests. Third, their efforts for the group must bear fruit. And finally, leaders must be skilled “entrepreneurs of identity” to shape group character. Think of Trump during his first presidential bid, when he portrayed himself as the embodiment of independent, tough-minded success and vowed to make America great again.

Of course, no leader has totally free rein to dictate a group’s identity, says Reicher. They must tap into its beliefs and desires, which makes the positions of leader and followers somewhat fluid.

Jacinda Ardern hugs a woman following the Christchurch mosque killings in March 2019



sense of the rise of Ardern in New Zealand and Marin in Finland. These countries are both relatively small and isolated, and under reasonably low levels of threat.

Furthermore, once in power, leaders set the tone of how a group reacts to a genuine threat. Following the mosque shootings in Christchurch last year, for example, Ardern focused on consoling people and bringing society back together. In responding to covid-19, she has exhibited openness, decisiveness and empathy – traits mirrored by other prestige leaders including Tsai Ing-wen in Taiwan and Angela Merkel in Germany.

But are these nothing more than just-so stories? Mansbridge thinks the idea that we tend to prefer “strong men” in the face of threat is an “interesting and fruitful hypothesis”, but it needs to be explored further. Dorothy Carter, a psychologist who heads the Leadership, Innovation, Networks, and Collaboration Lab at the University of Georgia is less equivocal. “The evidence is pretty strong to suggest that when people experience threat, due to conflict or economic

insecurity, for example, they tend to be more willing to grant leadership to potential leaders who exhibit dominant leadership behaviours,” she says. The evidence is there, agrees Wendy de Waal-Andrews, who studies social relations in groups and organisations at Vrije University. However, she isn’t convinced that the rise of dominance leadership is recent. War and natural threats were probably frequent in prehistoric times, she says. “The difference with modern societies may not be so much the extent to which leaders with a dominant style emerge, but their ability to remain in a leadership position after the immediate threat has passed.”

One possible explanation for the pre-eminence of dominance leadership in today’s world is a sort of global arms race. “When big countries start to elect authoritarian leaders, then other countries feel they have to do that as well,” says van Vugt. “And that’s a real warning, I think, for the stability of world peace and world order.” It isn’t that dominance leaders are inherently bad, but – whether from the right, left or centre of politics – it ➤

is in their interests to emphasise potential threats and play on people's fears.

However, van Vugt and Smith identify a way that we might shift the balance more towards prestige leadership. Other animals tend to rely on different leaders depending on the situation. If the group is threatened, it is generally a male, or males, who will lead the defence or counter-attack. But when it comes to deciding when to move on, find food or seek sanctuary, a female is more likely to take the lead. "Females, particularly elderly females, often have the most experience and knowledge, so they are followed to food resources, watering holes and to safe places away from danger," says Smith. Some human societies have traditionally adopted a similar approach. For example, the traditional authority system of the Navajo people in the south-west US had distinct leaders of war and peace, and also separate leaders for hunting, medicine and ceremonial songs. Of course, all societies have experts who lead in their own field. Yet countries and organisations currently tend to devolve ultimate power to a single leader at the top.

Dethroning dominance

In an attempt to buck this trend, some businesses are consciously promoting a more distributive approach to leadership. Gore-Tex in the US and Semco in Brazil, for instance, have adopted a system of decentralised management called holacracy, which gives decision-making powers to fluid teams, who can then choose the best person for a particular job. It has been argued that flatter organisational structures like these also help get more women into leadership roles, which might give another boost to prestige-style leadership. However, Carter is sceptical. "There is evidence to suggest that men tend to be granted leadership informally in self-managing teams more often than women, despite equal capabilities," she says.

At the national level, it may be even harder to shift away from dominance leadership. The difficulties are exemplified in US politics, according to van Vugt. Before the 2016 presidential election, he and his colleagues

For the Navajo, a healer was traditionally one of several leaders with distinct remits



BETTMANN ARCHIVE

How to be a good leader

How effective are our world leaders? According to a 2014 survey of World Economic Forum members, not very. To be better, respondents said that leaders should develop greater empathy and courage, work more collaboratively and prioritise social justice and well-being over financial growth. That same year, the Oxford Character Project was launched, with a mission to do just this. As part of the project, Edward Brooks heads the Oxford Global Leadership Initiative, a course for postgraduate students that seeks to develop key virtues including humility, honesty, generosity, gratitude and service.

Last year, a preliminary analysis found that the initiative produces measurable growth in gratitude and service, and helps students to assess humility and generosity in leaders. Brooks hopes that virtue education will become integrated into leadership courses elsewhere. We need a new generation of wise leaders and good thinkers, he says, "with a deep commitment to serve the welfare of society".

used their model to predict a Trump victory over Hilary Clinton. This time around, given the current US position both domestically and in its relations with other powerful countries such as China and Russia, and given who leads these countries, it again seems unlikely that a prestige-style opponent could beat Trump. His inept response to the Black Lives Matter protests and to the threat posed by covid-19 may act as a counterbalance. Still, things don't look good for Democratic challenger Joe Biden. "Biden has been counting on a prestige approach, appealing to people who fear and detest Trump's dominance model," says Mansbridge.

Despite the trajectory we appear to be on, van Vugt believes that things could change. "One result of economic prosperity is that people want more freedom, a more liberal approach, which favours more prestige-based leaders," he says. Mansbridge, meanwhile, sees hope in research suggesting that humanity is becoming less violent. As people become increasingly interdependent, both within and between nations, dominance leadership undermines our goals and the need for prestige leadership increases. "If that is the case," she says, "then Jacinda Ardern in New Zealand and Sanna Marin in Finland are the wave of the future." ■



Emma Young is a writer and journalist based in Sheffield, UK. Her latest book is *Here Lie the Secrets*

Signal Boost

Welcome to our Signal Boost project. In these difficult times, we are offering charitable organisations the chance to take out a page in *New Scientist*, free of charge, so that they can get their message out to a global audience. Today, a message from **Technicians Make It Happen**



Across science and industry, technicians work behind the scenes to keep everything going and make the next breakthrough possible. But their contribution can often be overlooked. The Technicians Make it Happen (TMIH) campaign exists to champion technicians and address the preconceptions of the general public.

The campaign uses case studies of real-life technicians, working in a wide range of fields, to help young people, parents and teachers understand who technicians really are. The covid-19 crisis has shone a light on technicians, many of whom are working tirelessly to meet needs like producing PPE, testing, and keeping digital infrastructure running.

Throughout the pandemic, TMIH has collected and promoted the contributions of technicians across the UK, which you can read on their Twitter (@technicians_mih) and their website technicians.org.uk. They want to ensure that when the world comes out of

this crisis, the vital work of technicians doesn't fade back into the background.

As well as outreach, TMIH supports the Technician Commitment, an initiative to ensure visibility, recognition, career development and sustainability for technicians working in higher education and research. Universities and research institutes become signatories and pledge action on the key challenges affecting their technical staff.

In the UK, 90 institutions have already committed to the initiative and work is underway to develop a culture where technical careers are recognised, respected, supported, developed and aspired to as

professional careers.

Learned societies and professional bodies are also engaging in the Technician Commitment, and organisations are working collaboratively to influence policy around technical roles and careers to support the technical community. Since the initiative launched in the UK, the Technician Commitment has gained interest from institutes in the USA, China, New Zealand and Australia, amongst others.

If you would like to learn more about technicians, Technicians Make it Happen or the Technician Commitment, you can visit our website at technicians.org.uk

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If you are a charitable organisation working in science, medicine, technology, education or conservation, and would like to find out more about this project contact Chris Martin on chris.martin@newscientist.com

The climate fight after coronavirus

Corinne Le Quéré advises the UK government on how to get to net-zero emissions. The pandemic gives us a unique chance to make the changes required, she tells Adam Vaughan

THE lockdowns imposed in many countries in response to the coronavirus have caused a dramatic reduction in our carbon emissions. But there is already evidence that this won't last. So how can governments build on this moment, as they plan for economic recovery, to make progress towards net-zero targets?

Corinne Le Quéré has a few ideas. A French-Canadian climate scientist at the University of East Anglia in Norwich, UK, she is an expert on the policies required to meet those targets and an advisor to the UK and French governments, both of whom have committed to reach net zero by 2050.

Le Quéré is also a leading authority on the carbon cycle, with a particular interest in what will become of natural carbon sinks, such as forests and oceans, in a warming world. Earlier this year, she was awarded the Dr. A. H. Heineken Prize for Environmental Sciences, the Netherlands's most prestigious international science award.

Adam Vaughan: What do you expect will happen to global carbon dioxide emissions this year?

Corinne Le Quéré: Over the past decade, emissions had been going up about 1 per cent per year. Since March, with the confinement and the restraints on travel, there has been a really big effect. Our estimates suggest a reduction in emissions of between 4 and 7 per cent this year. This is



huge. What's going to happen after that depends on how we're going to approach the economic recovery. In 2009, during the financial crash, emissions dropped 1.4 per cent. They then grew more than 5 per cent in 2010, which brought us exactly back to where we were – square one – like nothing had happened. There is a big risk for that now as well.

Which way do you think the post-coronavirus economic recovery will go?

It could be that governments do exactly what they know best, like build roads and finance the big carbon-emitting industries. But there is an opportunity to invest in the green economy now because renewable energy is a lot cheaper than in 2010 and we have all the knowledge required to make the batteries that can store that energy. Will that happen? Possibly in the UK. I would say even probably in Europe. It's not a given, but the signs are reasonably good. Whether it will happen worldwide is a bigger question. It's a little bit early to say.

What lessons, if any, does the covid-19 crisis hold for our efforts to avoid dangerous warming?

Well, first to take risks seriously – and the fact that we're very vulnerable. The UK is vulnerable because we have so many inequalities in society, and you can see how the crisis hits poor people harder. We have to rebuild society in a way that makes it a lot more resilient to climate-related events. I think what's happening also reveals that behavioural change is not enough. The vast majority of emissions remain, and the only way to reduce those is with structural changes to economies and industries.

In terms of cutting emissions, what are some of the things that we have been doing during lockdown that might be worth continuing?

When we go back to work, it is going to be problematic because social distancing is difficult on public transport. We have to instead encourage those who can work at home to do so, and to get as many people as possible who can't to cycle or walk to work. ➤

Electric bikes are increasingly affordable, which opens the possibility of cycling from suburbs in a way that didn't exist before.

What about flying?

Aviation has always been very problematic for climate change. There's no credible way to have net-zero emissions by 2050 and aviation as it was before covid-19, and the industry didn't engage at the right level on cutting emissions. Before this crisis, the push was for bigger airports and so on. Now, with covid-19, the number of flights has been cut by 75 to 80 per cent. It is going to be years before they can even think about going back to the passenger levels they had just a few months ago.

So now we have the opportunity to ask: what is an appropriate number of flights? We could have some leverage, too. The aviation sector has had exonerations for taxes that were completely unjustified. They haven't had the net-zero target, which is also unjustified. So I think these are the two levers governments can use when awarding recovery packages to aviation companies.

What should governments be doing to take advantage of the opportunities at the moment to rethink economies and societies?

Government investments post-coronavirus should focus on those actions that both support workers and enable the structural changes needed to deliver net-zero emissions, so we are more resilient in the future. In terms of investments, these should include support for the full electrification of transport, massive renovations of buildings and tree-planting and restoration of natural habitats. Actions that lock us into fossil fuels, such as building roads, should clearly be avoided.

In the UK, how big is the gap between the government's legislation targeting net-zero emissions by 2050 and the policies required to get us there?

The UK has been very successful in the power sector, moving out of coal in particular by taxing it and providing subsidies to renewables. But the UK has been behind on

"There is no way to have net-zero emissions and aviation as it was before covid-19"

strategies and implementation to move forward on buildings, transport and agriculture. The government has recently published a road transport decarbonisation strategy, which had some really good points in it. So there are things in the making, but we are not there at the moment. When you look at what the UK has delivered, it's not been enough.

What policies must the UK implement to stand a chance of hitting net zero by 2050?

Two-thirds of UK emissions are due to transport, buildings (mainly heating) and industry. Government departments should have ambitious implementation strategies in each of these sectors. One thing that has worked well in the UK is the clear signal the government has provided to move away from coal power generation and to phase out petrol and diesel cars from, currently, 2035 and gas boilers in new homes from 2025. These announcements need to be accompanied by a clear trajectory, with support to develop skills and supply chains, ensure performance and compliance and an appropriate carbon price on the use of fossil fuels. The UK also urgently needs to grow and manage its woodland so biomass can play its important role, and to develop carbon capture and storage, which will be a key asset in the transition to a zero-carbon economy.

You are an expert on the global carbon cycle. How has our understanding of where our CO₂ emissions end up improved over the years?

We have two sources of emissions – fossil fuels and land use change – and three places where those emissions end up – the carbon sinks of the atmosphere, land and ocean. If we had perfect knowledge and perfect data,

then the five terms would add up to exactly zero every year – and, of course, they don't. We call this mismatch the carbon budget imbalance: it's really like a quantitative measure of the things we don't know. The cutting-edge research is to find out what is behind that.

Any working hypotheses?

It's likely to come from either the ocean sink or the land sink or both, rather than the emissions, because the structure of this imbalance hasn't changed in 60 years and the emissions have quadrupled. If it came from some uncertainty in the emissions, then it would have been a lot smaller at the beginning of the time series and bigger now, and it's not. A possible explanation is that most models don't have nitrogen limitation, where lack of nitrogen impairs plant growth and therefore how much CO₂ they absorb.

Overall, what is happening to our natural carbon sinks?

The weakening of the Amazon rainforest as a sink is really, really scary. We need the carbon sinks to become stronger to help us in the management of this decarbonisation

REUTERS/HENRY NICHOLLS





During lockdown, cyclists flocked to The Mall in London, which is usually choked with traffic

process. To achieve net zero, we need to have bigger carbon sinks. That's because most activities that emit CO₂ can be cut down to zero, but not all. Agriculture or aviation can't be, for example, at least not with foreseeable technologies. We need to be able to offset those emissions by actively removing CO₂ from the atmosphere, creating anthropogenic carbon sinks that go beyond the natural carbon sinks that already exist.

The simplest way to create a carbon sink is by planting trees. The trees store carbon in their branches and roots, and with time, the soil carbon also builds up. We need to increase the forest cover enough that we build up that carbon biomass, and this offsets the emissions we cannot bring down to absolute zero.

You previously instigated an annual effort to keep track of global emissions. To what extent can we trust emissions data from governments?

Governments' reports to the United Nations are also scrutinised, checked by independent experts and validated by a team of experts at the UN Framework Convention on Climate Change, the UN wing that deals with international climate actions. The issue

is that, for the moment, only a subset of countries does this. Under the Paris Agreement, all countries will need to report, but it will take some time to scale up.

Isn't it critical that we have some independent measure of carbon emissions to track countries' progress under the Paris climate deal and hold them to account?

Absolutely. We now have satellite data, which measures vertical columns of CO₂ in the atmosphere above a given location. But we have to be realistic about what these observations will be able to do. I think, at least in the next 10 years, the best case would be to raise questions about the accuracy of emissions reports.

One of the big messages that the public picked out of the UN climate science panel's special report in 2018 was that there are "12 years to save the world", to ensure global warming doesn't exceed the target limit of 1.5°C. How helpful was that?

I didn't find it super helpful. What are you going to do in 10 years' time? You're just going to hope people will have forgotten you've ever said that. I understand that it gave

a sense of urgency that wasn't there before, but it's not 12 years anymore. I'm going to work on climate change all my life. If we miss the 1.5°C target, then I will fight for 1.6°C or 1.8°C, and if we miss the 2°C target, I will fight for 2.4°C. So for me, the fight is permanent. The lower the level we're fighting for, the better it is. There are some degrees of warming I don't even want to think about.

You said at a talk two years ago that before you die, you think you will live in a world where people no longer eat animals and can breathe clean air in the middle of cities. Do you still think that's the case?

The state of the science is clear. We have the Paris Agreement. We've had all the youth coming up and saying "we want a better world". We're not over the big polluting phase, but we've progressed in our thinking enormously. There is no real obstacle other than within ourselves. ■



Adam Vaughan is chief reporter at *New Scientist*



Seeing the dark

Could a billion-sensor array detect dark matter all around us – through its gravity?
Adam Mann weighs up an audacious proposal

RIGHT now, roughly half a proton's worth of dark matter is passing through your thumb. That points to the really exasperating thing about this mysterious stuff. Astronomical observations tell us that the gravity of something huge and unseen is tugging on stars and galaxies, making them whirl faster than they otherwise would. They suggest there is an awful lot of whatever it is – a whopping five times more than ordinary matter. And yes, we can even calculate how much of it should be passing right through us here and now.

Yet open the box, and there's nothing there. A no-show of dark matter in experiments designed to detect it on Earth increasingly has physicists questioning every notion they have about it. Now, a group of them is proposing we cut to the chase by focusing on the one thing we can say for certain about dark matter: that it interacts through gravity. We can use that, they say, to detect its ghostly gravitational influence as it passes through us and everything else.

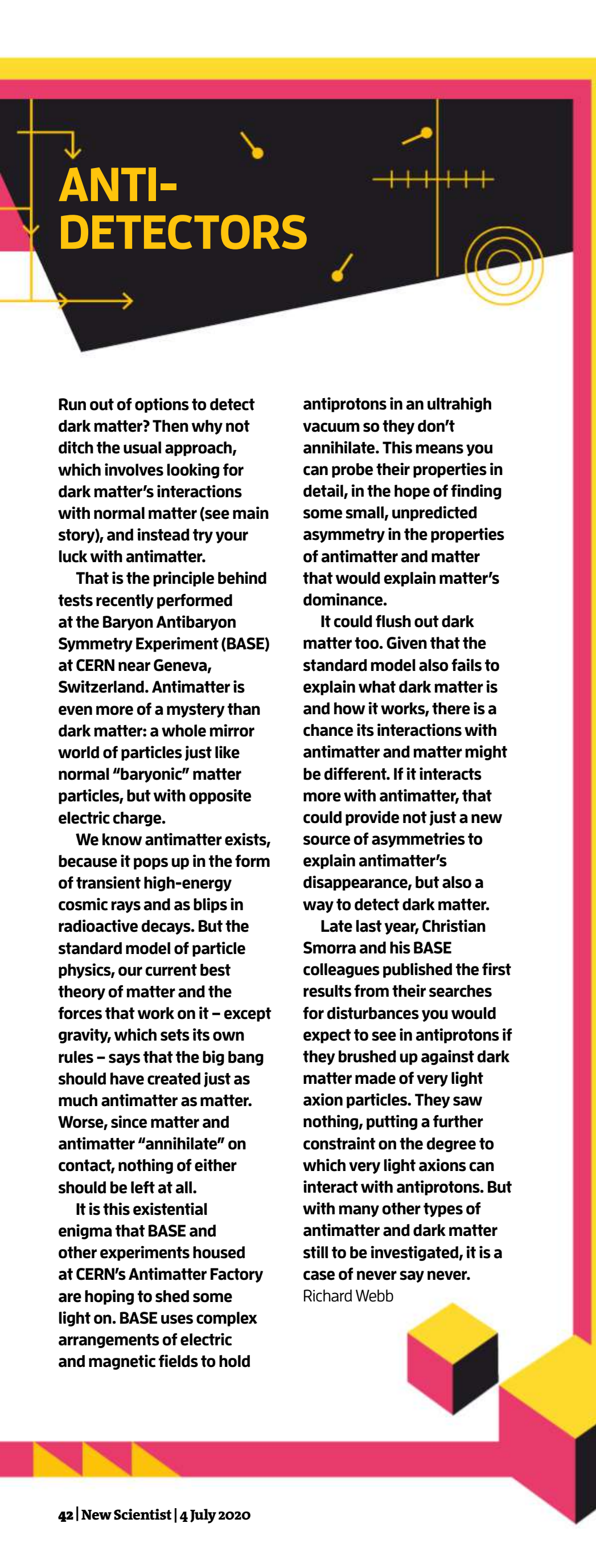
Well, possibly. Gravity is such a ridiculously weak force that detecting dark matter's touch directly would involve connecting together as many as a head-spinning billion mini-sensors, each one more sensitive to tiny disturbances than the huge set-ups used to spot gravitational waves. Then again, that worked, so why not this? "It's new, it's exciting,

it's coming out of left field," says Rafael Lang, a particle physicist at Purdue University in West Lafayette, Indiana. "We all agree that it's a bit crazy, but I think everybody will give you a different idea of how crazy it is."

It might seem ridiculous to say gravity is a weak force, given the calamitous effects it has if, say, you step out of an aeroplane in mid-flight without a parachute. That's true enough – but equally, you buck the gravity of an entire planet with ease every time you pick up your phone. To put a physicist's measure on that, the gravitational attraction between two protons is roughly 40 orders of magnitude, or 10 thousand billion billion billion billion times, weaker than their electrostatic repulsion.

Gravity's comparative feebleness is one of its many mysteries. Another is why it is the only one of the four fundamental forces of nature that can't be described using quantum mechanics. Physicists have searched for decades for an overarching framework that might combine quantum theory with Albert Einstein's space and time-warping general theory of relativity, which describes gravity, but they have had little success.

This was the ballpark that theoretical physicist Daniel Carney at the University of Maryland and his colleagues were playing on in 2017. They were considering how to design an experiment to search for the graviton, ➤



ANTI-DETECTORS

Run out of options to detect dark matter? Then why not ditch the usual approach, which involves looking for dark matter's interactions with normal matter (see main story), and instead try your luck with antimatter.

That is the principle behind tests recently performed at the Baryon Antibaryon Symmetry Experiment (BASE) at CERN near Geneva, Switzerland. Antimatter is even more of a mystery than dark matter: a whole mirror world of particles just like normal "baryonic" matter particles, but with opposite electric charge.

We know antimatter exists, because it pops up in the form of transient high-energy cosmic rays and as blips in radioactive decays. But the standard model of particle physics, our current best theory of matter and the forces that work on it – except gravity, which sets its own rules – says that the big bang should have created just as much antimatter as matter. Worse, since matter and antimatter "annihilate" on contact, nothing of either should be left at all.

It is this existential enigma that BASE and other experiments housed at CERN's Antimatter Factory are hoping to shed some light on. BASE uses complex arrangements of electric and magnetic fields to hold

antiprotons in an ultrahigh vacuum so they don't annihilate. This means you can probe their properties in detail, in the hope of finding some small, unpredicted asymmetry in the properties of antimatter and matter that would explain matter's dominance.

It could flush out dark matter too. Given that the standard model also fails to explain what dark matter is and how it works, there is a chance its interactions with antimatter and matter might be different. If it interacts more with antimatter, that could provide not just a new source of asymmetries to explain antimatter's disappearance, but also a way to detect dark matter.

Late last year, Christian Smorra and his BASE colleagues published the first results from their searches for disturbances you would expect to see in antiprotons if they brushed up against dark matter made of very light axion particles. They saw nothing, putting a further constraint on the degree to which very light axions can interact with antiprotons. But with many other types of antimatter and dark matter still to be investigated, it is a case of never say never.

Richard Webb

a hypothetical quantum particle that would carry gravity. As they were thinking of possible confounding background effects, someone pointed out that dark matter flying through the lab might conceivably introduce noise. "We said, 'Ha ha, very funny,'" says Carney. "But then we made an estimate and realised that's not noise – that's a signal."

That's because our best devices can now sense bewilderingly small forces, down to about a zeptonewton. A newton is roughly the force you exert against gravity to hold an apple in your hand. A zeptonewton is 10^{-21} , or a million million billion, times smaller than a newton – roughly the force you would exert picking up a strand of RNA.

Carefully balanced

Sensors that can see the tiny displacements caused by zeptonewton forces take us beyond the precision frontier established by the US Laser Interferometer Gravitational-Wave Observatory (LIGO) in 2015 when it made the first direct detection of a gravitational wave. These ripples in space-time are caused by far-off, cataclysmic mergers of massive objects such as black holes and are a key prediction of Einstein's relativity. Detecting one involved bouncing laser beams many times back and forth through concrete tunnels between two reflecting mirrors, positioned kilometres apart, to measure changes in distance 10,000 times smaller than the width of a proton.

Researchers in many labs are tinkering with zeptonewton sensors. One version that Carney and his colleagues are interested in balances a glass bead a few hundred nanometres across in a laser beam, and cools it to a fraction of a degree above absolute zero in an ultrahigh vacuum. Disconnected from its surroundings, the bead is free to move in response to hidden particles or forces – be they gravitons or, as the researchers calculated, chunks of dark matter. A salt-grain-sized lump of dark matter weighing about a millionth of a gram, for instance, would cause the bead to vibrate measurably if it happened to fly within a millimetre.

This simple idea is a world away from the complex interactions that current, so far unsuccessful, methods of dark-matter detection rely on. These focus on theorists' favoured guise for dark matter, particles known as WIMPs (see "How (not) to find dark matter", page 44), and probe mass scales far



“This simple idea is a world away from the complex detectors we rely on now”

lower than the microgram masses the new detectors would be most sensitive to. The higher range, known as the Planck scale, would instead contain objects that are extremely compact yet incredibly massive, making them subject to both quantum mechanics and general relativity. If new particles and forces existed at this scale, they might not just solve the dark matter puzzle – they could provide crucial hints, too, into how to unify these two theories.

The new detector would be agnostic as to what exactly this dark matter would be. It might be a collection of dark particles similar to visible molecules, a bunch of black hole remnants or a topological defect in space-time. Or it could be a curled up cosmic string as favoured by string theory – a prominent attempt to combine quantum theory and general relativity – or hypothetical extra-large WIMPs created shortly after the big bang, dubbed WIMPzillas.

Were such a detector to find anything, it

LIGO’s concrete tunnels are home to the most sensitive detectors so far built

would be big news. “The first thing you do, which earns you the Nobel prize, is you show that dark matter is real,” says David Moore, an experimental particle physicist at Yale University. Even if a detector found nothing, it would tell physicists that the mass range it was looking at is empty of dark matter.

There are still a few hurdles to jump before that becomes reality, however. For a start, there’s how you distinguish the tiny shaking of a bead from other, equivalently sized gravitational effects – say an elevator descending in a distant part of the lab building. Such effects have been known to confound previous attempts to measure the fundamental strength of gravity.

There is a workaround. Earth is ploughing through a thicket of dark matter as it, and the entire solar system, rotates around the centre of the Milky Way at some 800,000 kilometres per hour. Carney and his colleagues showed that if you arranged many of the new zeptonewton sensors in a regular three-dimensional grid they would vibrate in a coordinated manner when a dark matter nugget passed. In a similar way, LIGO and its European partner, VIRGO, require signals from multiple detectors at the same time to ensure their gravitational-waves are real.

Here’s the snag, however. Given the calculated local density of dark matter, an experiment that is a cubic metre in size would need somewhere between a million and a billion hypersensitive sensors spaced between a centimetre and a millimetre apart to uncover dark matter’s signature within a year. With a single zeptonewton sensor currently costing around \$1 million, the price would need to come down considerably for it to be feasible. Then you would need ways to skirt less worldly problems, such as the stringent limits that the fuzzy laws of quantum mechanics set on measurement precision at such small scales.

Then again, these are just the sort of problems that experimental physicists love to overcome. “This is really the opening shot in a longer conversation,” says Gordan Krnjaic, a theorist at Fermi National Accelerator Laboratory near Batavia, Illinois, who is part of Carney’s team.

He and around 30 other physicists gathered at the University of Maryland last ➤

October for a two-day brainstorming session to try to fill in the details of the vision. Work is now in full flow. Later this year, Lang and his colleagues hope to take data from a simple prototype of the sensor to see how strong a gravitational response they can get from particles that pass by with masses of a few millionths of a gram. Carney is doing something similar with instruments at the National Institute of Standards and Technology in Washington DC, while Moore wants to build arrays of around

“Ultimately, the hope is that these efforts might reveal new aspects of reality”

10 ultrasensitive sensors within the coming year, providing insights into constructing set-ups with larger numbers.

Ultimately, the hope is that as these efforts progress, they might reveal not just the identity of dark matter, but entirely new aspects of reality. Visible matter is made from an astounding wealth of particles and forces, and a fair number of physicists suspect dark matter might be as well. The same types of sensors that could feel dark matter's extremely tiny gravitational kick would be useful to search for this “dark sector”. Several researchers who attended the October meeting are currently looking for a dark force that could subtly affect neutrons at close range – an effect some think we have already seen hints of in controversial recent experiments that observed anomalous effects within helium and beryllium nuclei.

Such an ambitious programme naturally invites scepticism. “It’s not fundamentally impossible,” says Thomas Corbitt, an experimental physicist at Louisiana State University in Baton Rouge. “But it’s really, really hard.” Whether something at the scale of the full array would be the best use of limited funding remains an open question, he adds.

Meanwhile, the WIMP detectors could still turn up trumps, rendering the whole enterprise redundant. Just last month, the XENON1T collaboration at Italy’s Gran Sasso National Laboratory announced a tentative signal, not of WIMPs, but of axions, an alternative guise for dark matter. Or a breakthrough may come from a different direction entirely (see “Anti-detectors”, page 42). But such developments wouldn’t exclude the existence of the more massive forms of dark matter that the gravitational experiments are aiming to discover. “There’s a sense that we want to cover all our bases,” says Tongyan Lin, a theoretical particle physicist at the University of California, San Diego. “Maybe we’re potentially missing out on something that could be detectable.”

For the naysayers, Lang points to LIGO as a role model. “Someone said 30 years ago, ‘We can detect gravitational waves, but we need to measure the distance between two mirrors to a tiny fraction the size of an atom,’” he says. “This is obviously crazy, and yet they did it.” ■

HOW (NOT) TO FIND DARK MATTER

Current searches for dark matter concentrate on the form that, until recently, most theorists expected it to come in: as a weakly interacting massive particle, or WIMP. These emerge naturally from a theory called supersymmetry, which extends the current “standard model” of particle physics, and so ties up many of its loose ends.

WIMPs would be expected to have a mass of between 50 and a few thousand times that of a proton, and interact with regular material not just through gravity, but also through the subatomic weak force,

hence the name. That supplies a theoretically easier way of looking through them than by their gravitational interaction (see main story): by their weak-force recoil as they encounter the nuclei of normal atoms.

The current state of the art experimental set-up involves large vats containing a tonne or more of liquid xenon, sitting in underground mines to protect the vats from interfering cosmic rays. Smaller versions of such experiments running for the past 30 years have routinely seen a whole lot of nothing. The same goes for the

particle-smashing Large Hadron Collider at CERN near Geneva, Switzerland, which should have produced particles predicted by the simplest versions of supersymmetry by now, casting further doubt on whether they exist.

With no WIMPs in the bag so far, a flowering of new dark matter searches is focusing instead on ultralight “axions”, which would weigh a millionth or even a billionth of the mass of an electron. While there have been recent tentative hints, it is still too early to say whether there is anything there either.

Adam Mann



Adam Mann is a freelance writer based in Oakland, California

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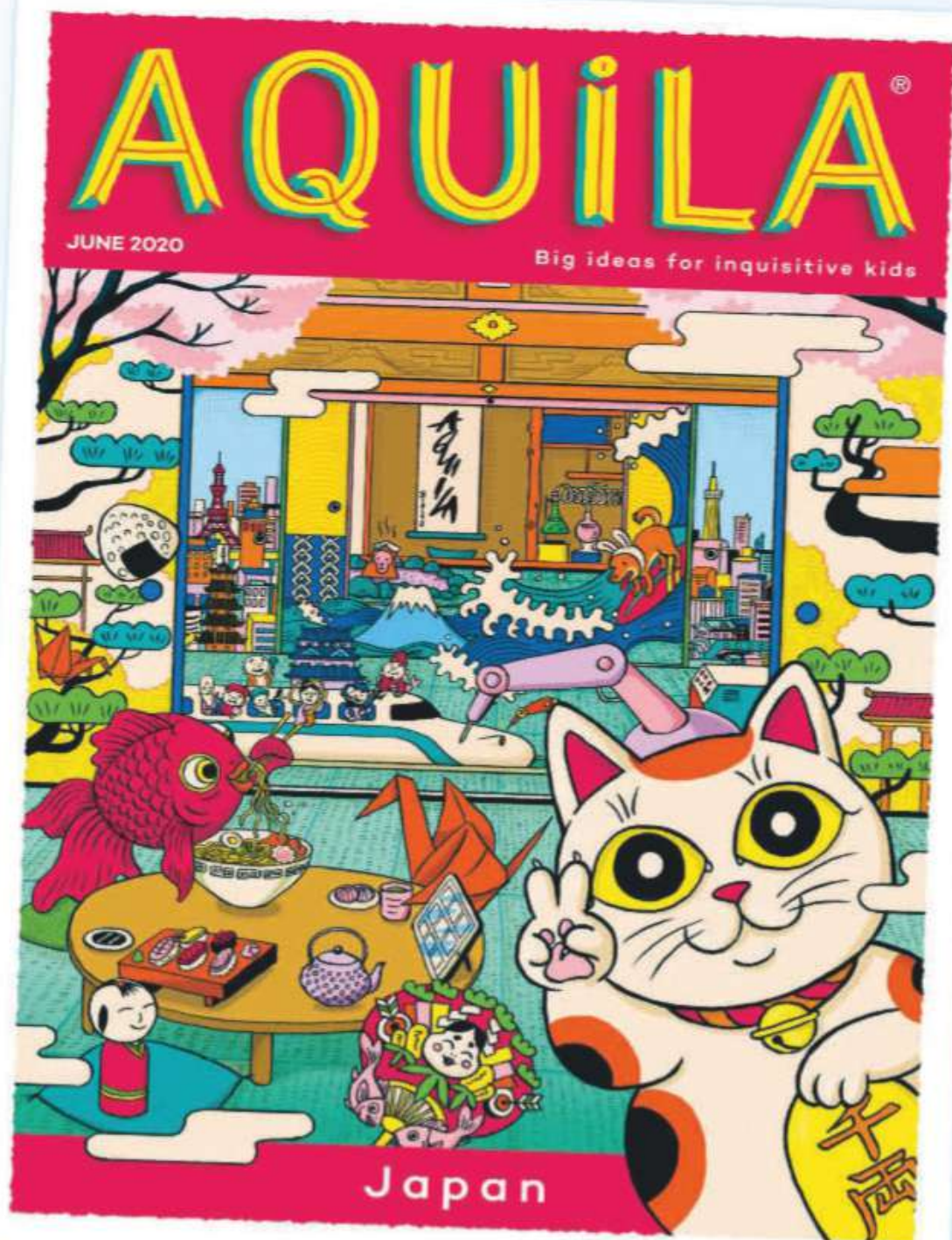
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RICHARD ROBINSON - BRIGHTON SCIENCE FESTIVAL

Could superintelligences of our creation in some way turn against us or supersede us on Earth? That idea is a staple both of science fiction and discussions surrounding how artificial intelligence will evolve. In this classic *New Scientist* article, reproduced in our new *Essential Guide: Artificial Intelligence*, AI researcher Toby Walsh argues that while machines may well in the long run outsmart us, there are any number of reasons to believe they'll never usurp us.

HOWEVER you look at it, the future appears bleak. The world is under immense stress environmentally, economically and politically. It's hard to know what to fear the most. Even our own existence is no longer certain. Threats loom from many possible directions: a giant asteroid strike, global warming, a new plague, or nanomachines going rogue and turning everything into grey goo.

Another threat is artificial intelligence. In December 2014, Stephen Hawking told the BBC that "the development of full artificial intelligence could spell the end of the human race... It would take off on its own, and redesign itself at an ever increasing rate. Humans, who are limited by slow biological evolution, couldn't compete, and would be superseded." In 2016, he followed that up by saying that AI is likely "either the best or worst thing ever to happen to humanity". Other prominent people, including Elon Musk, Bill Gates and Steve Wozniak, have made similar predictions about the risk AI poses to humanity.

Hawking's fears revolve around the idea of the technological "singularity". This is the point in time at which machine intelligence starts to take off, and a new, more intelligent species starts to inhabit Earth. We can trace the idea of the technological singularity back to a number of different thinkers, including John von Neumann, one of the founders of computing, and the science fiction author Vernor Vinge.

The idea is roughly the same age as research into AI itself. In 1958, mathematician Stanisław Ulam wrote a tribute to the recently deceased von Neumann, in which he recalled: "One conversation centered on the ever accelerating progress of technology and changes in the mode of human life, which gives the appearance of approaching some essential singularity... beyond which human affairs, as we know them, could not continue".

More recently, the idea of a technological singularity

has been popularised by Ray Kurzweil, who predicts it will happen around 2045, and Nick Bostrom, who has written a bestseller on the consequences.

There are several reasons to be fearful of machines overtaking us in intelligence. Humans have become the dominant species on the planet largely because we are so intelligent. Many animals are bigger, faster or stronger than us. But we used our intelligence to invent tools, agriculture and amazing technologies like steam engines, electric motors and smartphones. These have transformed our lives and allowed us to dominate the planet.

It is therefore not surprising that machines that think – and might even think better than us – threaten to usurp us. Just as elephants, dolphins and pandas depend on our goodwill for their continued existence, our fate in turn may depend on the decisions of these superior thinking machines.

The idea of an intelligence explosion, when machines recursively improve their intelligence and thus quickly exceed human intelligence, is not a particularly wild idea. The field of computing has profited considerably from many similar exponential trends. Moore's law predicted that the number of transistors on an integrated circuit would double every two years, and it has pretty much done so for decades. So it is not unreasonable to suppose AI will also experience exponential growth.

Like many of my colleagues working in AI, I predict we are just 30 or 40 years away from AI achieving superhuman intelligence. But there are several strong reasons why a technological singularity is improbable.

The "fast-thinking dog" argument

Silicon has a significant speed advantage over our brain's wetware, and this advantage doubles every two years or so according to Moore's law. But speed alone does not bring increased intelligence. Even if I can ➤



WILL AI TAKE OVER?

make my dog think faster, it is still unlikely to play chess. It doesn't have the necessary mental constructs, the language and the abstractions. Steven Pinker put this argument eloquently: "Sheer processing power is not a pixie dust that magically solves all your problems."

Intelligence is much more than thinking faster or longer about a problem than someone else. Of course, Moore's law has helped AI. We now learn faster, and off bigger data sets. Speedier computers will certainly help us to build artificial intelligence. But, at least for humans, intelligence depends on many other things including years of experience and training. It is not at all clear that we can short circuit this in silicon simply by increasing the clock speed or adding more memory.

The anthropocentric argument

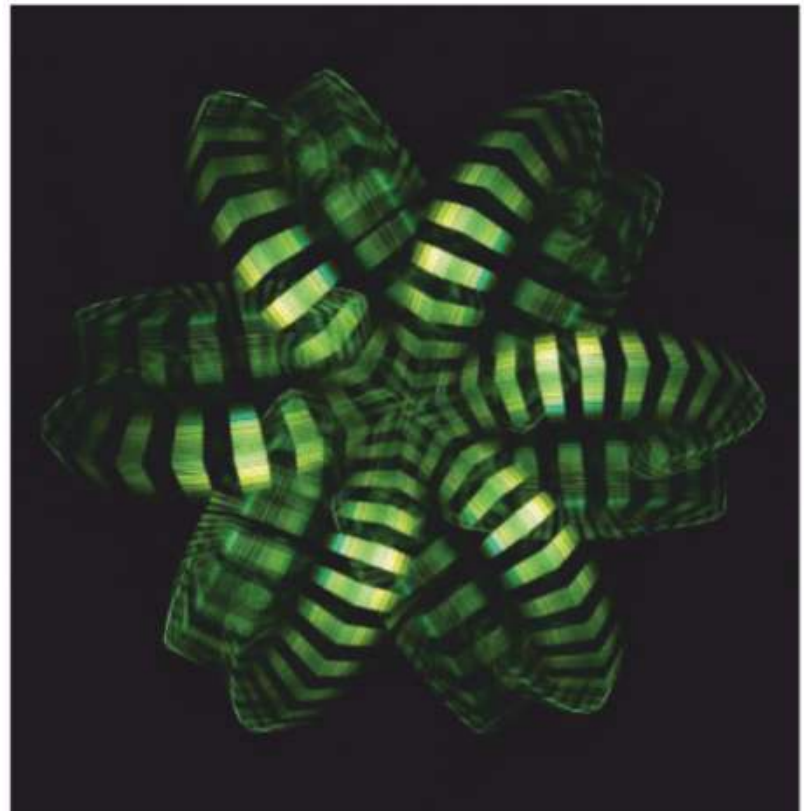
The singularity supposes human intelligence is some special point to pass, some sort of tipping point.

Bostrom writes: "Human-level artificial intelligence leads quickly to greater-than-human-level artificial intelligence... The interval during which the machines and humans are roughly matched will likely be brief. Shortly thereafter, humans will be unable to compete intellectually with artificial minds."

If there is one thing that we should have learned from the history of science, it is that we are not as special as we would like to believe. Copernicus taught us that the universe does not revolve around Earth. Darwin showed us that we are not so different from other apes. Watson, Crick and Franklin revealed that the same DNA code of life powers us and the simplest amoeba. And artificial intelligence will no doubt teach us that human intelligence is itself nothing special. There is no reason to suppose that human intelligence is a tipping point, that once passed allows for rapid increases in intelligence.

Of course, human intelligence is a special point because we are, as far as we know, unique in being able to build artefacts that amplify our intellectual abilities. We are the only creatures on the planet with sufficient intelligence to design new intelligence, and this new intelligence will not be limited by the slow process of human reproduction and evolution. But that does not bring us to the tipping point, the point of recursive self-improvement. We have no reason to suppose that human intelligence is enough to design an artificial intelligence that is sufficiently intelligent to be the starting point for a technological singularity.

Even if we have enough intelligence to design super-human artificial intelligence, the result may not be adequate to precipitate a technological singularity. Improving intelligence is far harder than just being intelligent.



CHRIS SEARLE

The "diminishing returns" argument

The idea of a technological singularity supposes that improvements to intelligence will be by a relative constant multiplier, each generation getting some fraction better than the last. However, the performance of most of our AI systems has so far been that of diminishing returns. There are often lots of low-hanging fruit at the start, but we then run into difficulties when looking for improvements. This helps explain the overly optimistic claims made by many of the early AI researchers. An AI system may be able to improve itself an infinite number of times, but the extent to which its intelligence changes overall could be bounded. For instance, if each generation only improves by half the last change, then the system will never get beyond doubling its overall intelligence.

The "limits of intelligence" argument

There are many fundamental limits within the universe. Some are physical: you cannot accelerate past the speed of light, know both position and momentum with complete accuracy, or know when a radioactive atom will decay. Any thinking machine that we build will be limited by these physical laws. Of course, if that machine is electronic or even quantum in nature, these limits are likely to be beyond the biological and chemical limits of our human brains. Nevertheless, AI may well run into some fundamental limits. Some of these may be due to the inherent uncertainty of nature. No matter how hard we think about a problem, there may be limits to the quality of our decision-

making. Even a super-human intelligence is not going to be any better than you at predicting the result of the next EuroMillions lottery.

The “computational complexity” argument

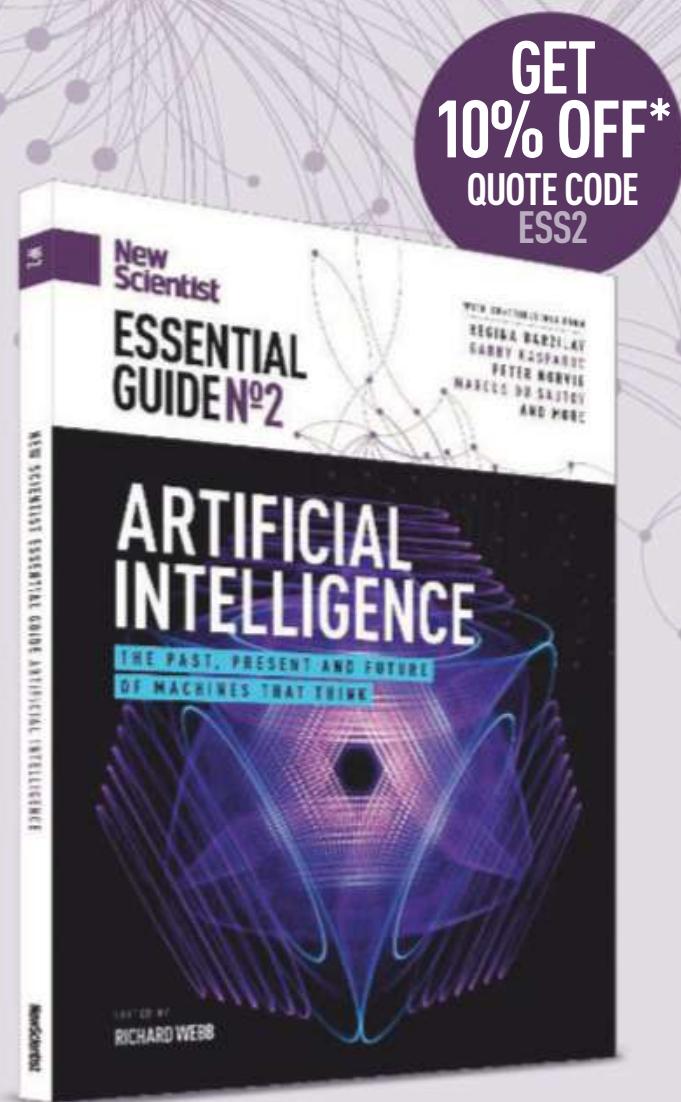
Finally, computer science already has a well-developed theory of how difficult it is to solve different problems. There are many computational problems for which even exponential improvements are not enough to help us solve them practically. A computer cannot analyse some code and know for sure whether it will ever stop – the “halting problem”. Alan Turing, the father of both computing and AI, famously proved that such a problem is not computable in general, no matter how fast or smart we make the computer analysing the code. Switching to other types of device like quantum computers will help. But these will only offer exponential improvements over classical computers, which is not enough to solve problems like Turing’s halting problem. There are hypothetical hypercomputers that might break through such computational barriers. However, whether such devices could exist remains controversial.

TWO FUTURES

So there are many reasons why we might never witness a technological singularity. But even without an intelligence explosion, we could end up with machines that exhibit super-human intelligence. We might just have to program much of this painfully ourselves. If this is the case, the impact of AI on our economy, and on our society, may happen less quickly than people like Hawking fear. Nevertheless, we should start planning for that impact.

Even without a technological singularity, AI is likely to have a large impact on the nature of work. Many jobs, like taxi and truck driver, are likely to disappear in the next decade or two. This will further increase the inequalities we see in society today. And even quite limited AI is likely to have a large influence on the nature of war. Robots will industrialise warfare, lowering the barriers to war and destabilising the current world order. They will be used by terrorists and rogue nations against us. If we don’t want to end up with Terminator, we had better ban robots in the battlefield soon. If we get it right, AI will help make us all healthier, wealthier and happier. If we get it wrong, AI may well be one of the worst mistakes we ever get to make. ■

TOBY WALSH is professor of artificial intelligence at the University of New South Wales in Sydney, Australia, and author of books including *Machines that Think: The Future of Artificial Intelligence* and *2062: The World that AI Made*



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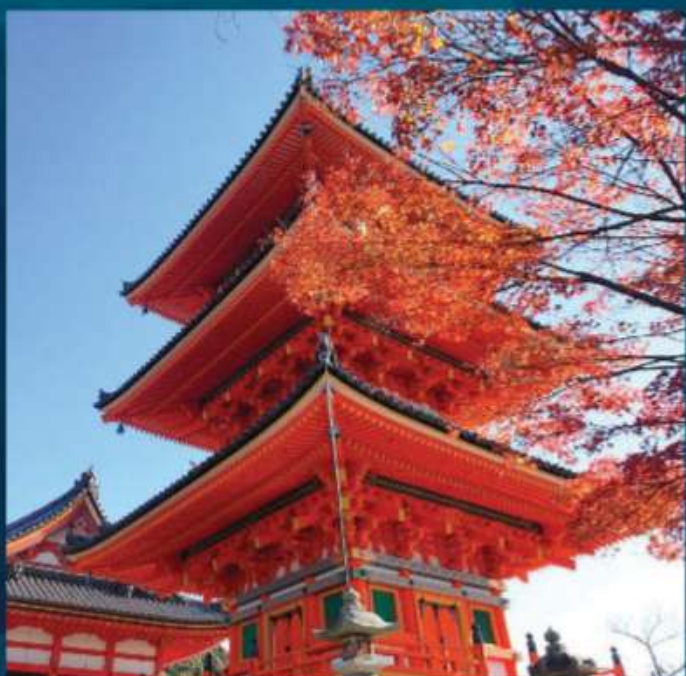
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Explore now, travel later

We were really excited by the launch of New Scientist Discovery Tours this year. Its concept of travel with experts on board and in the company of like-minded travellers who enjoy science and discovery promised a range of unique experiences. But Covid-19 had other plans.

Looking to the future, however, we are now focusing on next year's tours. On these pages you'll find just a few of them. We are not currently taking reservations, but if a specific tour lifts your spirits, why not register your interest and we will contact you when the time is right. Plan now – passport not required.



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October 2021

Japan: Nature, culture, science

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CZECH REPUBLIC

April and September 2021

Kepler's Prague: Music of the spheres

Discover the legacy of Kepler and Brahe in Prague, a city where astronomy, maths, music and art connect. Kepler became the father of modern astronomy supported by Brahe's observational data, considered the most accurate in pre-telescopic astronomy, in this beautifully preserved "city of a hundred spires".

Our tour with astronomer Jane Green will journey to the heart of early science and take in Prague's medieval marvels, including the world's oldest astronomical clock, Prague and Benátky Castles, and the Lobkowitz Palace, home of the composer Dvořák.

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March and November 2021

The science of the Renaissance

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Complement these with fascinating stories of polymaths such as Da Vinci and Galileo, as well as a wealth of lesser known scientists and artists, who thanks to the patronage of families such as the Medicis helped cement Italy's role at the forefront of scientific endeavour during this period.



ANTARCTICA

November 2021

The science of Antarctica

Join us aboard the *Magellan Explorer* for an exclusive fly-cruise expedition to South Georgia and the Antarctic Peninsula, exploring the world's largest ocean sanctuary and most pristine marine ecosystem. Follow in the footsteps of the great explorers and scientists such as Shackleton and Amundsen, whilst marvelling at imposing icebergs, ancient glaciers and ice floes onto volcanic beaches.

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USA

May 2021

The history and future of space exploration

From the first rockets, to the iconic Apollo moon missions, space stations and developing space tourism industry, this comprehensive tour visits key sites from over half a century of space exploration. Covering NASA space centres and several museums in Orlando and Houston, plus the Very Large Array telescope, Roswell and the stunning natural landscapes of New Mexico, it ends at Virgin Galactic Spaceport America, shortly to start commercial space flights.

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Puzzle

Can you work out the pattern from these tiles? **p54**

Cartoons

Life through the lens of Tom Gauld and Twisteddoodles **p54**

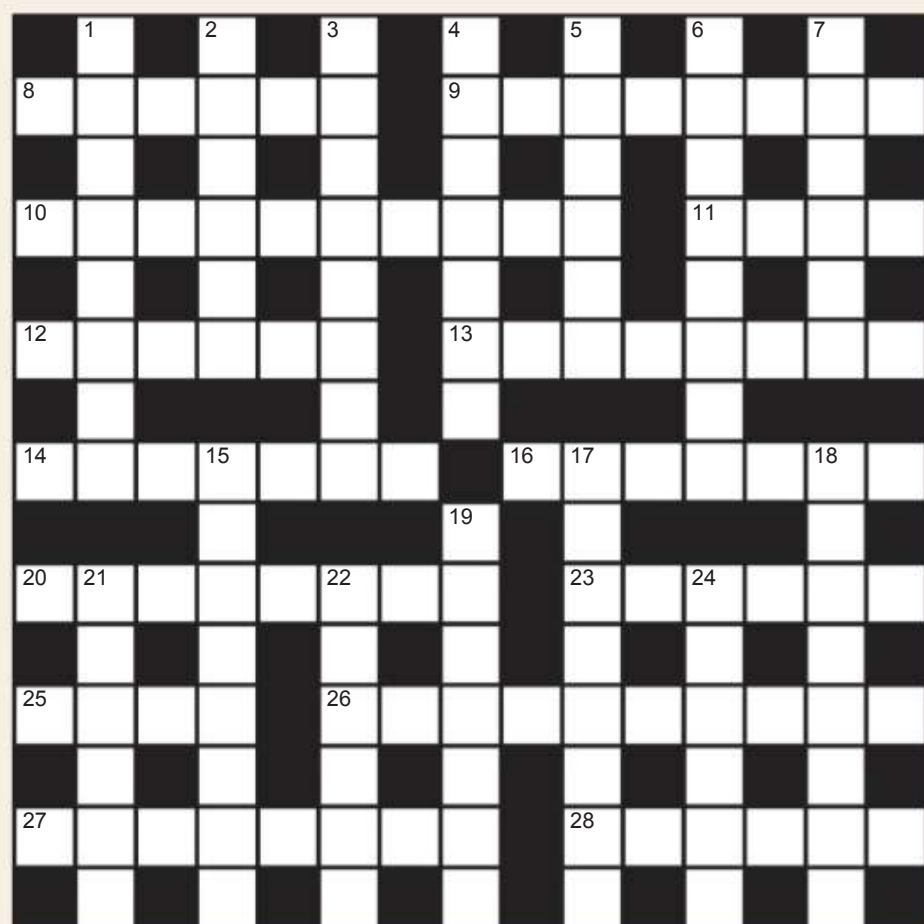
Feedback

Odorous offences in Bavaria and Vienna **p55**

The last word

Why some hairs stop growing at a certain length **p56**

Quick crossword #61 Set by Richard Smyth



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

- 8/11** Water iris; quarantine signifier (6,4)
9 *The Expression of the ___ in Man and Animals*, 1872 work by Charles Darwin (8)
10 Definitive proof (7,3)
11 See 8 Across
12 Paper product; assembly of cells (6)
13 Internal computer network (8)
14 Noam ___, linguist and activist (7)
16 GM automobile brand; Odawa chief (7)
20 Incandescent (5-3)
23 Breathe out; die (6)
25 Frozen precipitation (4)
26 1968 Jane Fonda sci-fi film (10)
27 Train component; field gun apparatus (8)
28 Of an anchor, just clear of the sea floor (6)

DOWN

- 1** ___ manoeuvre, choking remedy (8)
2 Parasitic flatworms; coincidences (6)
3 ___ flask, laboratory vessel connected to a kinked tube (4,4)
4 Flightless bird of the family Spheniscidae (7)
5 Series of linked AIs, often used maliciously (6)
6 To spread or bend (light or waves, perhaps) (8)
7 Inlet through which air reaches an engine (6)
15 Informal term for US debate over numeracy education (4,4)
17 *The ___*, 1971 post-apocalypse film starring Charlton Heston (5,3)
18 Branch of soil science concerned with crop growing (8)
19 Device that cranks an engine (7)
21 Aircraft housing structure (6)
22 Decorative disc for the wheel of a car (6)
24 US educational track for trainee doctors (3-3)

Quick quiz #58

- 1** Sharing its name with a 1998 film about a comet menacing Earth, which NASA probe rendezvoused with comet Tempel 1 in July 2005?
- 2** A large space rock collided with Earth 66 million years ago, possibly doing for the dinosaurs. What is the name of the crater it made?
- 3** What is the geological period dominated by the dinosaurs that this rock brought to an end?
- 4** Research in 2007 that sequenced proteins from *Tyrannosaurus rex* collagen indicated that it is almost genetically identical to that of what animal that still stalks the Earth?
- 5** What technique, often used in protein sequencing, determines a substance's composition by ionising it and measuring individual elements' mass and charge?

Answers on page 54

Cryptic Crossword #34

Answers

- ACROSS** **1** Aurochs, **5/15 Down/21** Sabre-toothed cat, **8** Thylacine, **9** Net, **10** Dodos, **12** Tension, **13/6 Down** Desert bandicoot, **14** At most, **17** Freight, **19** Outer, **22** Earthward, **24** Tacit, **25** Hodgkin
- DOWN** **1** Acted, **2** Ray, **3** Coarser, **4** Swifts, **5** Stern, **7** extinct, **11** Dyspeptic, **13** Deficit, **16** Starch, **18/23** Great auk, **20** Radon



Our crosswords are now solvable online
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Tom Gauld
for New Scientist

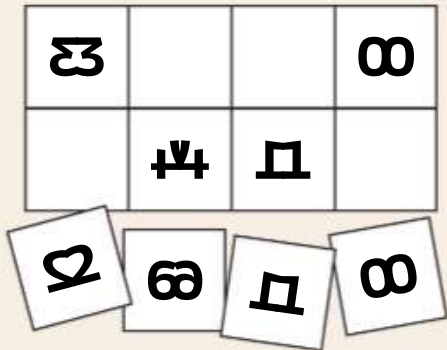


Twisteddoodles
for New Scientist



Puzzle
set by Hugh Hunt

#66 Square tiles



My daughter has made me a puzzle with eight square tiles that fit into a 2x4 grid. She tells me there is a connection between the symbols along the rows, and a simple rule that gets you from the symbols on the top row to the symbols below them.

She has put four of the tiles in place for me. Where do the other four go?

Answer next week

#65 Father figures

Solution

The pattern arises if the father's age is either a multiple of 9 (call this 9N) or is 9N - 1 when the baby is born. For example, if the dad is 27 when the baby arrives, then coincidences will happen every 11 years from 14 onwards: 14/41, 25/52, 36/63 and so on.

If the dad's age is, say, 26 when the baby is born, the dad will turn 27 before the baby turns 1, meaning their ages will then be 27/0. So on the dad's future birthdays, they will be 41/14, 52/25 etc. Of Jasmine's 90 Facebook friends, she should expect 2/9 of them (so 20 of her friends) to have experienced a dad-reversal at some point in their lives.

Quick quiz #58
Answers

- 1 Deep Impact. The probe released an impactor that excavated material from the comet's nucleus, revealing it to be surprisingly dusty
- 2 Chicxulub, after a nearby town in Yucatán, Mexico
- 3 The Cretaceous, which started 145 million years ago, after the Jurassic
- 4 The domestic chicken, *Gallus gallus domesticus*. Some researchers have questioned the finding
- 5 Mass spectrometry

Fruit of the mailroom

De gustibus non est disputandum, said the ancients. Or, to put it another way, don't yuck my yum – a precept Feedback does its best to live by. After all, what one person enjoys eating is none of another person's business. Provided, as a former *New Scientist* office regulation once had it, that it doesn't involve reheating fish in a communal microwave.

Occasionally, though, others in the great wide world are less enlightened than we are. Or, perhaps, the *gustibus* turns out to be *disputandible* after all.

An example of this kind crossed our desks recently courtesy of *The Times*, which reported that a post office in the Bavarian town of Schweinfurt had to be evacuated when a foul smell began emanating from a suspicious package.

Twelve workers apparently required medical attention, and the police and fire brigade were summoned to deal with what was taken to be a customs-cleared chemical weapon.

Fortunately, as it turned out, the source of the odour was a batch of four durian fruits.

Without straying too far from our guiding principles of good taste, Feedback can confirm that the durian has an aroma that is apt to trouble the uninitiated. We have, indeed, reported on its remarkable potency before.

In 2018, we wrote about a suspected gas leak, which prompted the evacuation of 500 people from a Melbourne university library, being ultimately traceable to a single rotting durian.

Parpetrators

From one foul smell to another, now, as *The Guardian* reports that an Austrian man has been fined for farting in the direction of police officers in Vienna.

Eager to dispel the impression of heavy-handedness, the police were quick to clarify that this wasn't a wind breakage of the casual, accidental kind, but – to



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Consideration of items sent in the post will be delayed

crib *The Guardian*'s translation – “a massive intestinal wind apparently with full intent”.

So what offence does that count as, Feedback wonders – possession with intent to distribute?

Whale fail

If nothing else, you would think that the saga of Boaty McBoatface would have taught public relations teams a valuable lesson. If you decide to let something's name be chosen by a popular vote, then prepare to never be able to say its name with a straight face ever again.

The latest victims of this trend are the city elders of Florence on the coast of Oregon. Having decided to crowdsource the name of a new park, they opened the vote to residents and let the people speak.

What they spoke, apparently, was

that they wanted the new green space to be named Exploding Whale Memorial Park. Odd, certainly, but not entirely random.

In November 1970, it turns out, a decomposing 7-tonne whale that had beached near Florence was deliberately blown up by local officials, resulting in what a local news agency referred to as a shower of blubber chunks. Presumably, this will be the first experiential attraction of the new Exploding Whale Memorial Park.

Have Bean

When it comes to a crisis like covid-19, the World Health Organization can use all the help it can get. Which is why, no doubt, it partnered with the biggest superstar at its disposal for its latest public service announcement. Do we have to

name them, or is their identity so obvious that we needn't bother? Oh all right then, fine: it's Mr Bean. You know – Mr Bean, the oddly lovable klutz played by Rowan Atkinson who was a staple of nineties terrestrial television as well as noughties in-flight programming.

It is an odd choice, isn't it, to pick the world's clumsiest man to handle its most sensitive crisis. You would think that whomever the WHO (or should that be WHOEVER the whom?) chose would have a personality more well-suited to the task.

But perhaps Feedback is passing judgement too soon. It has been several years since we last clapped eyes on Mr Bean (whether on land or in flight) and who knows what he has been up to during that time? Perhaps he has devoted himself to acquiring a PhD in immunology (part-time, no doubt, in order to accommodate his rigorous schedule of gurning). Dr Bean. Now there's a name that inspires confidence.

Where in the world

It seems to us that, over the past few months, Feedback has namechecked every individual, living or dead, whose name had any kind of link to their profession, residence, hobbies or fate. Which is no doubt why our readers have taken to branching beyond nominative determinism in people to exploring nominative determinism in places. God help us.

“I thought you might be (slightly) amused to know that the fertility clinic which opened in Wickford, Essex a year or so ago is aptly named ‘Bourn Hall’,” writes Tony Budd, while regular Feedbacker Barry Cash points us to the long and storied history of police stations around the world supposedly located on “Letsby Avenue”.

We look forward with ever mounting pleasure to our upcoming secondment to No More Nominative Determinism Crescent, NO RLY. ■

Written by Gilead Amit

Worm welcome

Worms stir up soil. Why don't they harm plant roots?

Mike Follows

Sutton Coldfield, West Midlands, UK

There are estimated to be 7 million earthworms to every person on Earth and they are found in most ecosystems around the world. They are regarded as essential ecosystem engineers. As well as ploughing, aerating and helping to irrigate soil, they recycle nutrients and disperse seeds.

For many people, munching on living plant tissue doesn't fit with the earthworm's benign image. However, the common earthworm (*Lumbricus terrestris*) is a herbivore that consumes seeds and seedlings, with a preference for legumes. There are anecdotes of worms eating plant roots. Indeed, why would worms avoid eating living plant tissue, particularly if alternative food is scarce?

So long

Why do some hairs, such as in the eyebrows, only reach a certain length, while the hair on your head continually grows longer?

John Morton

Pontypridd, Mid Glamorgan, UK

Humans are unique in this respect. Have you ever seen a chimpanzee, or in fact any wild animal, that needs a haircut?

All the other great apes have a single type of hair that covers their bodies and which grows for a certain time and to a certain length. After a set time, the hair becomes quiescent and is eventually displaced by a new hair growing out.

Human body hair does the same, but head hair keeps growing for a longer time, about three years. Of the genes that control the production of keratin, the protein that hair is largely made of, most are the same in all the great apes. But in humans one, called *KRTHAP1* or *phihHaA*,



GUY CORBISHLEY/ALAMY

This week's new questions

Cyclic logic A triplet bike is lighter and has less resistance per person, so is more efficient than a tandem, which is more efficient than a regular bike. Does this trend hold however long the bike? *Simon Aldridge, London, UK*

Sea settlers Hydrothermal vents teem with life on a lifeless seabed. How are they colonised? *Howard Watkins, Reading, UK*

is a pseudogene – it is transcribed into RNA, but no protein is ever synthesised from it.

It has been theorised that the longer growth period of human head hair is due to this mutation in this gene.

You would think that the hair would get in the way, but it could be that having to look after this long hair improved social bonding in our ancestors after body hair was lost and people lived in small groups.

It is apparent in the present circumstances that well-groomed hair is important to people, and it is something that is very hard to do properly by yourself.

John Neimer

Wareham, Dorset, UK

The curbs to eyebrow growth being self-limiting seem only to apply when one is young, or younger.

My experience is that my head hair still sprouts vigorously, except on top of my head, which has been follicularly challenged since I was in my late twenties.

But, since the age of about 50 years old, my hair on my ears,

nose and eyebrows also grows prolifically. I am now in my eighties and the hair that isn't on my head has to be routinely dealt with if I am not to resemble the Green Man.

Tony Dawson

Williamstown, Victoria, Australia

I suspect that this has at least something to do with genetics.

My maternal grandfather had spectacularly long eyebrows, which he never trimmed.

He was similarly well endowed with ear hair.

I seem to have inherited a similar condition. Because of the covid-19 lockdown, I haven't been to the hairdresser for some time and now my eyebrows have grown up to 30 millimetres long. I had one eyebrow hair that reached the end of my nose until I pulled it out. It is evident that shortness of eyebrows, or ear hair for that matter, isn't a universal trait.

How far can you extend bikes to increase their efficiency?

Christine Warman

Hinderwell, North Yorkshire, UK

It isn't actually the case that human head hair grows continuously, it is simply that it achieves far greater length than the hairs on the rest of the body.

How long head hair can grow depends on an individual's pattern of growth, which can vary considerably. I was told by my hairdresser that I could never grow my hair beyond shoulder length because my follicles had a short cycle of growth and renewal.

There are three stages of hair growth: the actively growing anagen phase, which may last for between two and eight years; a brief hiatus known as the catagen phase, in which the hair follicle shrinks; and the telogen phase, in which the follicle remains dormant for several months.

These three phases are followed by a renewal stage. In this phase, the old hair breaks off and is replaced by a new one. This process goes on all the time. Unlike some species, we don't moult. Still, we lose hundreds of hairs every day.

A further question is, why do humans have such long hair on their head, when much of their body, while not actually "naked", is thinly covered with hair?

This doesn't seem to be a primarily sexual characteristic, unlike the hair that emerges in certain areas after puberty, because head hair is present from early infancy.

One explanation is that hair on the scalp protects the top of the head and the ears from the sun, while a bare and sweaty body enabled early humans to be active in the heat of the African savannah. ■



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**Clare
Wilson**



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Dan Hooper, Theoretical Astrophysicist, Fermilab

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